DS. 7
1700

REPORT

OF THE

TECHNICAL MISSION

Appointed to Advise on the Production of Artificial Fertilisers in India

सत्यमव जयत

PUBLISHED BY THE MANAGER OF PUBLICATIONS, DELHI.
PRINTED BY THE MANAGER GOVT. OF INDIA PRESS, SIMLA 1944.
REPRINTED AT THE SURVEY OF INDIA OFFICES (H. L. O.), DEHRA DUN 1949.

Price Rs. 1-12-0 *or* 2*s.* 6*d.*

PERSONNEL OF THE MISSION

Leader	MR. G. S. GOWING, B.A., F.R.I.C.
Members	MR. J. RIGG, M.SC.
	MR. T. H. RILEY.

TABLE OF CONTENTS

New Delhi, dated the 2nd November 1944.

To

THE SECRETARY TO THE GOVERNMENT OF INDIA,
DEPARTMENT OF SUPPLY,
NEW DELHI.

REPORT OF TECHNICAL MISSION.

SIR,

WE have the honour to present the Report of the Technical Mission appointed to advise on the production of artificial fertilisers in India.

Formation of Mission and terms of reference.

2. The formation of our Mission and terms of reference were intimated in the Government of India Press Note dated the 8th June 1944, which reads as follows :—

" A Technical Mission from the United Kingdom, headed by Mr. G. S. Gowing of Imperial Chemical Industries Ltd., together with one other member of Imperial Chemical Industries Ltd., and one of the Power-Gas Corporation Ltd., the latter representing the Association of British Chemical Plant Manufacturers, will visit India to advise on the production of artificial fertilisers for increasing food supplies. The Mission, acting for the Government of India, will undertake the following :—

(*i*) Investigate and report to the Government of India on the technical problems involved in the manufacture of Sulphate of Ammonia in British India in quantities up to 350,000 tons per annum.

(*ii*) Recommend, in the light of the raw materials and power available in India, the most economic method of manufacture.

(*iii*) Indicate the approximate capital cost of the plant or plants to be installed, and calculate the approximate cost of operations and production of finished Sulphate of Ammonia.

(*iv*) Recommend the most suitable site or sites for the erection of the plants concerned, taking into account the raw materials available and the most economic distribution of the finished products.

(*v*) Estimate the amount and approximate value of plant which it will be necessary to import from outside India making the fullest possible use of materials and labour available in India.

(*vi*) If, for any reason, it should appear that nitrogenous fertiliser, in a form other than Sulphate of Ammonia, can be more satisfactorily manufactured under Indian conditions generally or locally, consider and recommend from a technical point of view, the most economic method of manufacture of such alternative fertiliser.

(*vii*) Estimate the capital and operating cost of manufacture of such alternative nitrogenous fertiliser.

3. Prior to our arrival in India, the Government appointed a Consultative Committee to meet us in New Delhi for preliminary discussions and examination of the statistics and information which had been collected to assist us in our investigations. The constitution of the Committee was announced in a further Press Note dated the 10th June, 1944, to the following effect :—

Constitution of Consultative Committee.

" To receive the Technical Mission coming to India to advise on the production of artificial fertilisers, the Government of India have appointed a Committee with Sir James Pitkeathly, Officer on Special Duty, Department of Supply, as Chairman and with the following as Members :—

Mr. R. W. Targett, Director General of Supply ; Mr. S. C. Roy, Assistant Agricultural Commissioner with the Government of India ; Dr. V.K.R.V. Rao, Director of Statistics, Department of Food ; Dr. E. L. G. Clegg, Director, Geological Survey of India ; Mr. H. M. Mathews, Electrical Commissioner with the Government of India ; Sir T. Vijayaraghavachariar (Prime Minister, Udaipur State) on behalf of the Chamber of Princes ; Sir Gopalaswamy Ayengar, Chairman, Travancore Chemical & Fertiliser Co. Joint representative of Travancore and Mysore ; Sir Jnan Chandra Ghosh, Director, Indian Institute of Science ; Mr. Kapilram H. Vakil, Managing Director, Tata Chemicals, Ltd ; Mr. P. R. Crerar, Director of Chemicals, Department of Supply ; Dr. M. S. Patel, Deputy Director. Chemicals Directorate, Department of Supply ; Mr. C. C. Broughton, Works Manager, Cordite Factory. Mr. J. B. Langford, I.C.S., Deputy Secretary, Department of Supply, will be Secretary to the Committee.

After preliminary discussions with the Committee and examination of the statistics and information which have been collected in advance by the Departments of Government, the Mission will proceed on tour, and will visit those areas and sites which may be considered suitable for the erection of plants and the economic manufacture and distribution of artificial fertilisers.

The Provinces will be associated with the Mission through their selected representatives, who will deal with all enquiries and tours, and will prepare and submit any suggestions and information desired to be placed before the Mission."

Sir Shanti Sarup Bhatnagar, Director, Board of Scientific and Industrial Research, was later invited to become a Member of the Committee and attended the meetings.

4. We arrived in India by air on the 10th June, 1944, and were met at Karachi by Sir James Pitkeathly, Chairman of the Consultative Committee. On the following day we proceeded to New Delhi and commenced preliminary discussions with the officials of the Department of Supply and other officers of the Government of India. During these discussions, it became evident that, before we could deal adequately with the investigations necessitated by our terms of reference, visits to Provinces and States in certain parts of India would be necessary. Accordingly, we drew up, in anticipation of our meeting with the Consultative Committee, our first tour programme covering the places which we considered should be visited at the earliest opportunity. This was subsequently modified and extended as circumstances required. In order that the officials of the Provincial Governments and States might have a clear indication of the information

Proceedings of the Mission.

we desired to obtain from them, the Department of Supply, at our suggestion, issued a communication in which the information required was set out in some detail.

Meetings of Consultative Committee.

5. The first meeting of the Consultative Committee under the presidency of The Hon'ble Dewan Bahadur Sir A. Ramaswami Mudaliar, Supply Member, Government of India was held on the 19th June, 1944, and subsequent meetings were held on the two following days. The discussions at the meetings and the observations made by the Membersof the Committee were of great interest and much valuable information and guidance was given to us.

6. An account of the subsequent proceedings of the Mission is given in Annexure A.

Acknowledgments.

7. We desire to express our indebtedness to all the officials of the Government of India, of the Provincial Governments and of the Indian States with whom we came into contact during the course of our investigations and most gratefully to acknowledge the assistance we have been given, the readiness with which our requests for information have been met and the courteous reception accorded to us during our visits.

We are also greatly indebted to the firms, commercial organisations and individuals who have furnished information for our use and to the engineering and other concerns who granted us facilities to visit their works and factories.

We wish particularly to express our deep appreciation of the great help given to us by Sir James Pitkeathly, Chairman of the Consultative Committee, whose guidance on numerous aspects of the problem was invaluable. He accompanied us throughout the period of the investigation and placed his unrivalled knowledge and experience freely at our disposal.

We also wish to tender our thanks to Mr. C. C. M. Broughton, Works Manager, Cordite Factory, Aruvankadu who accompanied us during our tour and whose knowledge of large-scale chemical operations in India has proved very valuable to us. Our acknowledgments are also due to Dr. H. Crookshank, Offg. Director, Geological Survey of India and Mr. E. B. Lewis, Chief Mining Engineer, Central Excise, Salt Range, Khewra for valuable assistance during the examination of the gypsum deposits of Punjab and Rajputana.

Our thanks must also be given to the clerical staff of the Department of Supply for their consistent good work during the investigation.

ALTERNATIVE TYPES OF NITROGENOUS FERTILISERS.

Preliminary observations.

8. As a preliminary to the discussion of the principal terms of reference relating to the manufacture of sulphate of ammonia, it is necessary to dispose of the question of alternative nitrogenous fertilisers. In Clauses VI and VII of the terms, consideration of such fertilisers is stipulated if it is found that they can be more satisfactorily manufactured, either locally or generally, under Indian conditions, in which case the appropriate capital and operating costs are to be calculated for the particular process or processes considered most economic. Clearly, in approaching the whole question of fertiliser production, the type of fertiliser required must be decided before processes of manufacture can be investigated and estimates of cost prepared. We therefore summarise here our conclusions regarding the relative merits of sulphate of ammonia and other nitrogenous fertilisers in relation to Indian conditions.

Ammonium nitrate.

9. The most important alternative nitrogenous fertiliser is ammonium nitrate and, at an early stage in our investigations, the conclusion was reached that, although neither technical difficulties nor lack of suitable raw materials render the manufacture of sulphate of ammonia unattractive for India, yet there is no doubt that ammonium nitrate would be a cheaper product in terms of total nitrogen content. This difference is due principally to the widely separated sources of the raw materials required for the manufacture of sulphate of ammonia. The possibility of substituting nitrate for sulphate in all or any of the principal regions of fertiliser consumption has therefore been considered.

10. Ammonium nitrate possesses certain properties which militate against its direct use. It absorbs moisture from the air, leading to losses and severe caking troubles, especially in damp weather. It is liable to decompose, sometimes explosively, especially when subject to high temperatures, and this characteristic makes it essential to exercise great care in storage of the material. Ammonium nitrate therefore is not suitable for use as a fertiliser without admixture with some other material which facilitates its storage, handling and application to the soil. In drier countries, it is possible to use ammonium nitrate as a fertiliser when mixed with ground chalk or limestone, and attention has recently been given to the development of methods of coating the crystals with resins and other materials with the object of overcoming the caking difficulty. We do not, however, consider that the best methods of treatment at present available can be considered to yield a product which is comparable with sulphate for the conditions of storage, transport and application likely to be encountered in India. It is also necessary to consider the properties of ammonium nitrate as a fertiliser, since it does not follow that a material which has been used abroad would be equally suitable for Indian soils and crops. During our tour, the agricultural experts of the provinces and states visited were consulted on the possibility of using ammonium nitrate as a fertiliser, should a product with suitable handling properties become available. We were informed that practically no field-work has been carried out with nitrate and that therefore very little is known about its value as a fertiliser under Indian conditions. None of the agricultural experts was prepared to recommend its adoption as the standard fertiliser for his area without carrying out extensive field trials, which would need to be spread over several seasons. There was also a general feeling that the Indian cultivator, being in many instances already accustomed to the use of sulphate of ammonia, would not accept readily a new

type of fertiliser requiring application in unfamiliar quantities, and that therefore the rapid expansion envisaged in the government scheme for the application of fertilisers to food grain crops might be retarded.

Urea and ammonium chloride.

11. Similar considerations apply to the use of other possible nitrogenous fertilisers, such as urea and ammonium chloride, which are not very largely used abroad and have also not received in this country the extensive field trials which would be necessary before they could be recommended for large-scale application.

Recommended fertiliser.

12. We have therefore arrived at the conclusion that the only nitrogenous fertiliser to be recommended for the project under consideration should be sulphate of ammonia. Looking into the future, however, and considering the possible production of fertiliser in quantities beyond the 350,000 tons per annum now under investigation, we are of opinion that work should be instituted to determine whether ammonium nitrate is a suitable fertiliser for Indian conditions.

METHODS OF MANUFACTURE OF SULPHATE OF AMMONIA

Description of processes of sulphate of ammonia manufacture

13. For the purpose of this report we may describe sulphate of ammonia as a nitrogenous fertiliser in which nitrogen, in the form of ammonia, is combined with certain elements to produce a compound which can be readily handled and applied to the soil. The manufacture of sulphate of ammonia is a highly technical subject and it may be useful if, at the outset, we give a brief description of the processes involved and state the reasons for our selection of the particular process we are recommending. The manufacture of sulphate of ammonia falls naturally into two stages :—

(*i*) the production of ammonia itself, and

(*ii*) its conversion into sulphate.

In the following paragraphs we shall discuss the methods employed in each of the two stages.

Processes of manufacture of ammonia.

14. Ammonia is a compound formed from three volumes of hydrogen and one volume of nitrogen and its manufacture consists in producing a mixture of the two gases in the correct proportions in a high state of purity and causing them to combine. Of the two gases it is the hydrogen which is the more expensive to produce and it is therefore upon the methods of producing hydrogen that the classification of methods of producing ammonia is naturally based. These methods may be grouped under the following headings :—

(*i*) Manufacture from hydrogen produced as a by-product in a chemical manufacturing process and from nitrogen produced either by the combustion of some of the hydrogen by air or by fraction of liquid air.

(*ii*) Manufacture from hydrogen separated from coke-oven gas by partial liquefaction, the nitrogen being obtained in one of the ways mentioned under (*i*).

(*iii*) Manufacture from hydrogen produced by the interaction of steam with the hydrocarbons in natural gas. In this case the nitrogen would be made by combustion of some of the natural gas by air.

(*iv*) Manufacture from hydrogen produced by the electrolysis of water and from nitrogen produced by the fractionation of liquid air.

(*v*) Manufacture from hydrogen produced by the direct reduction of steam by carbon, the nitrogen being produced by combustion of air and carbon either separately from, or preferably simultaneously with, the production of the hydrogen.

(*vi*) Manufacture from hydrogen produced by the steam iron process and nitrogen from the residual gases of this process.

The above processes have been considered with reference to their application to Indian conditions and the following are our conclusions.

Manufacture of ammonia from by-product hydrogen.

15. The manufacture of ammonia from by-product hydrogen is a process which is only applicable to small installations since by-product hydrogen will, in general, not be available in large quantities. Moreover, the economics of such production are inevitably bound up with those of the primary product and any diminution in the demand for the primary product will either reduce production of ammonia or have a large adverse effect upon its costs of production. The production of any considerable proportion of the 350,000 tons of sulphate of ammonia by this method is therefore not practicable, although the possibility of one or more small installations being economic cannot be entirely neglected. In the course of our investigations however we were unable to find quantities of by-product hydrogen sufficient for even the smallest economic ammonia unit and therefore this method of production of ammonia cannot be recommended.

Manufacture of ammonia from coke-oven gas.

16. The production of ammonia from coke-oven gas is a method which is utilised in a number of plants, although since these plants are generally of small size, the proportion of the world's total production of ammonia by this process is small. Moreover, for various reasons, the number of plants using this process is diminishing and many of them are now obtaining their hydrogen from the carbon-steam process. This process also involves, although to a lesser extent, dependence upon a raw material which is a by-product of another process—namely, the production of coke—and to this extent the cost of the ammonia will be dependent upon the demand for coke and for the usual by-products of a coking plant. In addition, the use of coke-oven gas for ammonia assumes that either waste coke-oven gas is available or that the heating value of the hydrogen extracted can be replaced by some other form of fuel gas. We therefore consider that the same arguments apply to the use of coke-oven gas as apply to the use of any other form of by-product hydrogen, namely, the undesirability of making any considerable proportion of the total production of sulphate of ammonia dependent upon another industry. We nevertheless investigated the possibility of using coke-oven gas in the Bihar coalfields but found that no supplies are at present available or likely to be available in the near future in such quantities as would suffice for the production of any reasonable proportion of the 350,000 tons per annum of sulphate of ammonia. For our purposes, therefore, the production of sulphate of ammonia from coke-oven gas cannot be recommended.

Manufacture of ammonia from natural gas.

17. The manufacture of ammonia from natural gas is a method which has come very much into prominence during the present decade and is likely to become more important in the future. Where natural gas is available in sufficient quantity, the manufacture of ammonia from the hydrogen produced by the decomposition of the hydrocarbons contained therein is a method which has been adopted in a number of recent plants. We have however been informed by the Geological Survey of India that sufficient quantities of natural gas are not available and therefore this process cannot be adopted in this country. It should, however, be emphasised that if natural gas in sufficient quantities should be found in India, consideration should be given to its use for ammonia manufacture as it is likely to prove an economic proposition.

Manufacture of ammonia from electrolytic hydrogen.

18. Many ammonia plants utilising electrolytic hydrogen as a raw material are in operation in various parts of the world, although, since the output of each individual plant is small, the quantity of ammonia produced by this method is a very small proportion of the whole. Since the hydrogen is produced by the electrolysis of water and the nitrogen by the liquefaction of air, the process requires no raw materials other than water and air and consequently can be operated wherever sufficient power is available. The process, however, requires a very large quantity of electric power (of the order of 4,000 kilowatt hours per ton of sulphate of ammonia) and therefore it cannot compete with a process using coke unless the power is obtained at a very cheap rate. Moreover, as will be shown in the paragraphs dealing with the conversion of ammonia into sulphate of ammonia, carbon dioxide, which is a by-product of the process using hydrogen produced by the reduction of steam, is required if the gypsum process is adopted. The electrolytic process is therefore confined, in practice, to the production of sulphate by means of the sulphuric acid process (see paragraph 23). It would, of course, be possible to produce the necessary carbon dioxide by burning limestone, but, since this would add materially to the cost of the finished product, still cheaper power would be necessary to compete with coke. Early in our investigation, it became apparent that nowhere in India was sufficient power available throughout the year for the production of any considerable proportion of the total quantity of fertiliser required. There was, however, the possibility that a small electrolytic plant might be an economic part of the whole scheme by virtue of special local conditions, such as a concentrated small demand at a long distance from the source of supply of coke, in a locality where electric power is available at a low price. Such, however, was not found to be the case and, as a result, we have reached the conclusion that the electrolytic process cannot be recommended for the whole or for a part of the 350,000 tons per annum production scheme.

Manufacture of ammonia from hydrogen produced by action of steam on carbon.

19 The next process to be considered, the so-called water-gas or semi-water-gas process is that utilised for the production of by far the largest proportion of the world's output of ammonia and is one which has been adopted for plants with outputs varying from twenty to one thousand tons per day of ammonia. In the earlier plants the hydrogen was produced by the action of steam on coke in a water-gas generator, the nitrogen being produced by the action of air on coke in an ordinary gas producer.

Latterly, however, the two operations have been combined in one, the necessary quantity of air being introduced with the steam in the generator, thus producing the so-called semi-water-gas in which there is sufficient nitrogen to enable the correct three to one hydrogen—nitrogen ratio to be attained after removal of other constituents. The majority of plants operating this process utilise coke as a source of carbon, but since coal is normally a cheaper starting material, recent developments have tended in the direction of attempts to replace coke by coal. Although this has the advantage of making use of the hydrogen in the coal, there are many disadvantages, among which are the formation of tar and the presence of hydrocarbons in the gas produced. This latter disadvantage is a very serious one in connection with the production of ammonia, since hydrocarbons are difficult to remove and their presence in the final nitrogen-hydrogen mixture necessitates heavy purging with consequent loss of hydrogen and low efficiency. Many attempts have been made to overcome the difficulty by destroying the hydrocarbons by cracking or decomposition by steam before the gas leaves the generator. A certain amount of success has been achieved after many years of intensive development work in the utilisation of brown coals and lignites, but it is our opinion that any such process would necessitate prolonged trials of Indian coals before it could be recommended as a basis for the expenditure of a large amount of capital.

Recommended form of carbon.

20. Carbon in another form—charcoal—has been suggested as an alternative to coke in India. So far as can be ascertained, this material has not been used for the production of water-gas or semi-water-gas, but if a charcoal of a sufficiently high quality can be produced, there would appear to be no insuperable difficulties to be overcome. Consideration has been given to the use of this raw material but we have reached the conclusion (see paragraph 40) that it cannot be recommended for use in the scheme of production under consideration. Taking all factors into account, we have formed the opinion that for the production of 350,000 tons per annum of sulphate of ammonia in the shortest possible time the only process to be recommended is the semi-water-gas process using Bihar coke, which is available in the quantities required. In arriving at this decision, we have not been unmindful of the fact that the resources of coking coal in India are not unlimited, and we are of opinion that the possibilities of utilising lower grade non-coking coal for gas production for ammonia manufacture should be investigated with a view to its possible use for future schemes of production.

Manufacture of ammonia from hydrogen produced by the steam-iron process.

21. This process involves the decomposition of steam in the presence of an iron-ore contact material at a high temperature ; the process is cyclic, the iron-ore being alternately oxidised by steam and reduced by suitable reducing gases. In the past this process has been confined to the production of relatively small quantities of high purity hydrogen for use in the edible oil industries, but, so far as we know, it has not yet been used for the production of hydrogen for ammonia synthesis on account of its high cost. During recent years, considerable improvements in the technique of the process have been evolved and the production of reducing gases is no longer restricted to the water-gas method, since it has been shewn that low-grade gases from inferior fuels are equally suitable as reducing mediums. This process has been kept in mind, but in view of the availability of good quality coke it is concluded that further consideration need not be given to it, particularly since a certain

amount of development would be required to translate from the existing scale of production to the larger scale required for ammonia manufacture. Where however economic factors compel the utilisation of fuels other than coke, this method for the production of gas for ammonia synthesis should be given careful consideration.

Methods of conversion of ammonia into sulphate of ammonia.

22. There are two methods used in the conversion of ammonia into sulphate of ammonia :—

(*i*) the sulphuric acid process ;

(*ii*) the gypsum or anhydrite process.

Sulphuric acid process.

23. In the first process, ammonia is combined with sulphuric acid to produce neutral sulphate of ammonia. Since large quantities of sulphuric acid are required (3|4 ton per ton of product) it is necessary to include, as part of the equipment, plant for the production of sulphuric acid. This is produced by burning either natural sulphur, pyrite or some other sulphur-containing ore such as zinc sulphide. In countries where there is a large number of gas works, a material known as " spent oxide ", which is the spent absorbent from the plant for removal of sulphur from town's gas, is also used. Since, however, India does not possess any of these materials in sufficient quantities, the sulphuric acid process for converting ammonia into sulphate of ammonia cannot be employed.

Gypsum or anhydrite process.

24. The gypsum process employs naturally occurring calcium sulphate either in the hydrated form as gypsum, or in the anhydrous form as anhydrite. The process consists in first carbonating (by the use of carbon dioxide) the ammonia to form ammonium carbonate and then reacting the solution of this salt with finely ground gypsum or anhydrite The resulting calcium carbonate in the form of precipitated chalk is filtered off and the solution evaporated to give sulphate of ammonia. We have satisfied ourselves that ample quantities of gypsum and possibly also of anhydrite exist in India and therefore this process is recommended for the conversion of ammonia into sulphate of ammonia.

Disposal of by-product.

25. It will be noted that calcium carbonate as precipitated chalk is a by-product of the process. It is possible to put this material to two uses :—

(*i*) for agricultural purposes as a dressing for land deficient in lime, for which purpose it has the advantage that it contains traces of sulphate of ammonia and

(*ii*) for the manufacture of cement.

It is therefore possible that from the disposal of this by-product some credit in the cost of manufacture of sulphate may be secured, but as this depends very much upon local conditions which may well change from time to time, it is always necessary to make arrangements for dumping the chalk in the vicinity of the plant. For this reason no credit has been assumed in the cost of manufacture of the sulphate. It should also be noted that carbon dioxide is necessary as a raw material for this process ; this is obtained in sufficient quantities as a by-product in the production of ammonia by the semi-water-gas process

but not by the electrolytic process. Had the latter been selected for the manufacture of ammonia, it would have been necessary to provide the carbon dioxide by burning the waste calcium carbonate to lime, utilising a make-up of imported limestone to cover the inevitable losses in this process. The system, while theoretically possible, has never been worked out in practice and would present difficulties owing to the finely divided nature of the by-product calcium carbonate. Such utilisation does not however come into question, since as was shown above the electrolytic process is, for other considerations, not recommended for the present scheme.

Process recommended.

20. In the foregoing paragraphs we have discussed, in some detail, the different processes by which sulphate of ammonia can be produced and our conclusion is that the method to be recommended is the manufacture of ammonia from coke and its conversion to sulphate by means of gypsum. Not only does this recommendation ensure that all the raw materials are wholly and abundantly available from Indian sources, but it has the further advantage of utilising processes which have been perfected over a long period of years, during which time many standardised items of equipment have been evolved. By the adoption of the method we have recommended, the delays in carrying out design and development work on items of equipment, which might be required for other methods, will be entirely eliminated. Furthermore, availability of standard designs of plant and equipment for the processes recommended will ensure an extensive choice of manufacturers, and thus obviate dependence on any particular industrial interest.

RAW MATERIALS FOR THE MANUFACTURE OF SULPHATE OF AMMONIA

27. The raw materials with which we are at present concerned are :—

1. Natural sulphur
2. Pyrite
3. Anhydrite
4. Gypsum
5. Coke
6. Charcoal
7. Coal

Natural sulphur.

28. The Geological Survey of India reports as follows :—

"In India the only workable deposits of natural sulphur occur in Baluchistan. Since 1941, the Geological Survey of India have worked deposits of sulphur associated with volcanic ash on Koh-i-Sultan about 25 miles north of Nok-Kundi (28°48′ : 62°45′) in the Chagaï Agency of Baluchistan. There are two important areas of production, Batal and Miri, with total estimated reserves to date of 64,000 tons of ore equal to 26,100 tons of free sulphur".

"A deposit of sulphur in the Sanni area in Kalat State, about 110 miles south-east of Quetta, has been investigated recently, but the information accumulated indicates that it could not be developed economically".

From the foregoing it will be seen this material cannot be considered as a source of sulphur for the manufacture of sulphate of ammonia on the scale contemplated.

Pyrite.

29. In regard to the availability of pyrite, the view expressed by the Geological Survey of India is as follows :—

"Although there are several small occurrences of pyrite in India only two have prospects of being workable, but even these could sustain only a relatively small sulphuric acid industry".

Pyrite cannot therefore be considered as a raw material for the project in hand.

Anhydrite.

30. In the report prepared for our guidance by the Geological Survey of India, only a few small deposits of anhydrite, which were merely of mineralogical interest, were reported but it was stated that much of the so-called gypsum in the Punjab is a mixture of anhydrite and gypsum. During our visit to the Khewra Salt Mine, we were shown the new tunnel which is now being driven in connection with further development of the salt mine workings and during our inspection we noted what appeared to be a promising deposit of anhydrite. At our suggestion, the Government of India have agreed to an investigation of this possible source being undertaken at once and have sanctioned the expenditure required for this purpose. Although the result of this investigation is not available in time for inclusion in this report, it is a matter of urgent importance that it should be available in sufficient time to allow the plant to be designed for the use of anhydrite, should the deposit prove sufficiently extensive. We cannot too strongly stress the importance of finding a workable deposit of high-grade anhydrite, as in addition to the saving in consumption, as compared with gypsum, due to the absence of the 20% water in the latter, the process for the manufacture of sulphate of ammonia is rendered easier and less costly both in capital charges and running costs. In paragraph 111 the advantages of anhydrite over gypsum are discussed in more detail. The estimated costs of working this deposit by underground mining are given in Appendix 3, on the assumption that on further investigation the deposit is found to be sufficiently extensive to warrant the expenditure of capital in developing the mine.

Gypsum.

31. On the basis of information furnished by the Geological Survey of India, we have investigated the best deposits of gypsum, so far as known at present, in this country. The deposits investigated were those occurring in the following areas :—

(1) Rajputana (in the Bikaner and Jodhpur States).

(2) Punjab (in the Salt Range).

(3) Madras (in the Trichinopoly area).

During our investigation of the gypsum deposits occurring in Rajputana and the Punjab we were accompanied by Mr. E. B. Lewis, Chief Mining Engineer, Salt Range, Central Excise, and he has prepared for us very valuable reports dealing fully with the methods of working recommended, the estimated cost of the plant, equipment and services required and the probable cost per ton of gypsum at each place. These costs are summarised in Appendix 3.

Rajputana.

32. These deposits occur at Jamsar in Bikaner and at Badwasi, Pilanwasi and Dakoria in Jodhpur. They are at present being worked by simple methods but we consider that by the use of modern equipment they can be quarried easily and cheaply on a large scale. A report by the Geological Survey of India on these occur-

rences is given in Appendix 2. Samples of these deposits have been analysed and show a gypsum content of 83% ; they have also been tested for suitability in the production of sulphate of ammonia and we are of opinion that they will be satisfactory. The estimated costs of production given in Appendix 3 relate to the Jamsar deposit only as we recommend that, in the first instance, this deposit should be exploited in preference to others occurring in this area.

Salt Range.

33. Enormous quantities of good quality gypsum, much of which is massive, are to be found in the Salt Range. So far very little has been worked, but we consider that this is the most promising of the sources of supply. Samples of material from various parts of the district have been tested and appear to be satisfactory for the manufacture of sulphate of ammonia. As far as can be determined from surface samples, the gypsum content is higher than that of the Rajputana mineral, averaging 93-94%. An account of these deposits by the Geological Survey of India is given in Appendix 1, and in Appendix 3 estimates are given of the cost of developing and working one of the deposits in the Daud-Khel area. This occurrence was visited and we are satisfied that it will prove easy of exploitation. We have therefore recommended that a more detailed survey should be carried out by the Geological Survey of India.

Madras.

34. The gypsum deposits near Trichinopoly are spread over a large area and consist of veins and stringers of gypsum in clays and limestones. At present they are being worked by extremely primitive methods. Owing to the fact that the mineral is not massive, but only amounts to about 1.3% of the material excavated, thus necessitating washing in an attempt to free it from foreign matter, the resulting product is far from pure and difficulty will probably be experienced in obtaining a material of constant purity. Furthermore, as will be seen from the figures given in paragraph 115, the cost of gypsum from such a low grade source is certain to be so much higher than that of material obtained from more favourable deposits elsewhere that it can only be used economically when transport charges on the latter become excessive. There is also a small deposit of gypsum near Sulurpet in the Nellore area, consisting of crystals embedded in marine silts. Since the concentration is low and the mineral cannot be worked owing to floods for more than five months out of the year, the deposit is not recommended for consideration.

Recommended sources of gypsum and anhydrite.

35. Final recommendations regarding sources of gypsum and anhydrite cannot be made until the scheme of production of sulphate of ammonia is decided and the location of the factory or factories settled ; the possibility of utilising anhydrite is also uncertain until the reserves of this mineral have been determined by the survey now in progress. Generally speaking. however, it may be said that a factory in South India would find it more economic to make use of the Trichinopoly gypsum, and that factories in other parts of the country would draw their supplies from the Salt Range or Rajputana. More detailed discussion of this question will be found in paragraph 112 in which the advantages of various sources of supply are discussed in relation to the scheme of production of fertiliser actually selected.

Coke.

36. To obtain the best and most efficient result the coke used for the production of semi-water-gas should be metallurgical coke or gas works coke of good quality. In either case the coke should possess the following properties :—

(*i*) The ash of the coke should have a melting point above 1200°C, and preferably not lower than 1300°C, since an ash of low melting-point gives clinkering trouble with consequent serious reduction in output and efficiency.

(*ii*) Physically the coke should be sufficiently hard to withstand disintegration during handling and storage and also to resist being crushed in the deep bed employed in the semi-water-gas generator.

(*iii*) The volatile content of the coke should be low to avoid the formation of excessive quantities of hydrocarbons in the gases produced. Without additional expensive equipment, hydrocarbons are extremely difficult to remove completely in the final purification of the gas for ammonia synthesis, and if not removed they accumulate in the system and have to be purged with a consequent loss of hydrogen and nitrogen resulting in a higher consumption of coke.

(*iv*) The sulphur content of the coke should be low in order to reduce the cost of its subsequent removal and to avoid corrosion.

37. Our investigations have elicited the fact that gas coke is made on a very small scale at only two places in India and for this reason it has not been taken into consideration. The only metallurgical coke in India is manufactured in the Bihar-Bengal coalfields and we have satisfied ourselves that the coke produced there is of suitable quality for use in the semi-water-gas process for the production of ammonia although it is inferior in respect of ash content to the best foreign cokes and the consumption of coke per ton of product will, therefore, be somewhat higher than is the case in plant using the latter. We are also satisfied from information received that the quantity required (about 175,000 tons per annum) will be available.

Charcoal.

38. In connection with a plant in the Godavari Delta area of Madras it has been suggested that charcoal should be used as a raw material for gas production. We have investigated this suggestion paying particular attention to three aspects of the problem, (*i*) the difficulties involved in the production of charcoal in considerably greater quantities than are at present commercially available ; (*ii*) the technical aspects of the manufacture of gas suitable for ammonia production from the charcoal, and (*iii*) the economics of its use as compared with that of coke. For a 50,000 tons per annum sulphate of ammonia plant about 26,000 tons per annum of charcoal would be required, equal to about 75 tons per day. This will consume not less than 300 tons per day of wood, the exact figure depending upon the methods adopted for "burning". We have been informed that the yield of the forests in the area under consideration is about 12 tons per acre and that the regeneration period of the forest is about 30 years. To produce the above quantity of charcoal an area of about 20 square miles will have to be stripped each year and a total area of some 600 square miles set aside. In our opinion a number of difficulties will have to be overcome in developing charcoal production, among which are :—

(*i*) the difficulty of maintaining an adequate labour force in a remote and unhealthy region ;

(*ii*) the steadily shifting area of operation ;

(*iii*) the difficulty of arranging economic transport to rail head ;

(*iv*) the hold-up of production during the rains, with consequent need for the provision of covered storage ;

(*v*) the considerable loss due to handling between forest and factory ;

(*vi*) the difficulty of making adequate provision to ensure all the product being above a certain minimum standard of quality.

39. Turning to technical considerations, so far as we are aware, charcoal has not been used as a raw material for ammonia synthesis. Provided that volatile matter can be kept sufficiently low in the charcoal to avoid troubles due to the production of hydrocarbons in the gas, we see no reason why generators should not be designed to run on charcoal. On the other hand, if the volatiles cannot be kept low enough to prevent hydrocarbon formation then it will be necessary to provide plant for their removal. We are of opinion that no great difficulty would be experienced in overcoming these drawbacks, but consider that tests on a fairly large scale will be required, and these will take time. In the absence of an established industry producing high quality charcoal on the scale required for fertiliser production it has proved difficult to obtain a reliable price for this material. The best estimate presented to us has been prepared by the Madras Government in response to a request submitted by us when the use of charcoal was suggested ; the estimated figure is Rs. 40 per ton. This price does not differ materially from the price of Bihar coke delivered in the Godavari Delta area, but the consumption of charcoal per ton of sulphate would probably be slightly higher than that of coke.

40. These arguments may be summarised by saying that from price considerations alone there is certainly no advantage in the use of charcoal in place of coke, that there are uncertainties in the production and transport of the material and that possible development work in the exact method of utilisation might lead to some delay in the commencement of manufacture. For these reasons we are of opinion that a plant using charcoal should not be recommended as part of a scheme for the production of the required quantity of sulphate of ammonia at the earliest possible date, although there would appear to be possibilities for its use for any subsequent developments of fertiliser manufacture in the south of India.

Coal.

41. A considerable quantity of coal is required for raising steam for process purposes and for the production of power in a factory which does not rely upon external sources of power supply. In accordance with the information given to us, we are satisfied that there will be no difficulty in obtaining the quantity required (about 250,000 tons per annum). The estimates for plants in various parts of the country are based on coal obtained from the most convenient coalfield in each case. In general, we recommend in the interests of the conservation of the coal resources of the country that the lowest grade of coal compatible with economy in steam raising should be used. In this connection, it should however be pointed out that in the case of a coal-consuming unit at some distance from the nearest coalfield it is necessary to adopt a compromise between the use of high and low grade coal since, in the case of the latter, freight charges have to be paid on the useless constituents of the fuel.

REQUIREMENTS OF STEAM AND ELECTRIC POWER.

Sources of power supply.

42. In a factory for the production of sulphate of ammonia by the coke-gypsum process there is a demand for steam for heating and evaporating purposes and for the manufacture of hydrogen ; by far the greater part of this demand is for low pressure saturated steam which can conveniently be taken from the exhaust of a prime mover. Electric power is required for driving the various machines used in the process such as compressors, gasfans, pumps and conveyors. To produce one ton of sulphate of ammonia, steam equivalent to about 0.6 tons of coal is needed together with about 570 kilowatt hours of electric power. It is, however, possible to secure very considerable economy in the cost of steam and power, considered together, by raising steam in the factory at a high pressure and using this to drive electric generators by means of turbines constructed to pass out steam at a pressure suitable for process purposes. The saving in cost resulting from the adoption of this scheme is very considerable, since, if the thermal power is obtained from outside the factory, about 0.4 tons of coal would be used to produce the 570 kilowatt hours needed per ton of sulphate of ammonia, giving a total coal consumption of about 1.0 tons per ton of product. On the other hand, by combining power generation with steam production within the factory, a total consumption of only 0.7 tons of coal per ton of sulphate of ammonia is incurred, thus reducing the total coal consumption by nearly 30%. It is true, of course, that should power be available from a hydro-electric source, there will be no overall saving of coal, but rather the reverse, by generating power inside the factory. If such a situation should arise, the question of the cost of power would have to be investigated, the cost of the hydro-electric power being compared with the cost of generating power within the factory, based on a coal consumption considerably less than that of a normal thermal station and having the low overheads consequent on the generating station being an integral part of a large organisation. The precise power consumption, steam demand and steam conditions are matters which depend upon the detailed design of the factory. However, taking normal steam and power figures for coke-gypsum process and fixing the steam conditions at the maximum so far contemplated for Indian conditions (600 lbs. per sq. inch pressure and 800°F. total temperature), we find that approximately 90% of the necessary power can be generated from the steam required by the process. In practice this is a very convenient proportion, representing a reasonable compromise between the maximum economy obtainable by generating all the required power in the factory on the one hand, and the increased flexibility of operation resulting from the existence of a source of power which is not dependent on the factory steam demand on the other. In paragraph 111 the possibility of substituting anhydrite for gypsum is discussed and the consequent reduction in manufacturing cost is estimated ; this change in raw material has the effect of reducing the steam demand and therefore the power generated by roughly 5%. The quantity of power to be obtained from an external source will therefore be increased by this amount.

Steam or electric drives.

43. As we have already explained, steam is required for various process purposes and power for driving the various machines employed. It will be realised that it would be possible to drive some of the larger machines directly by steam and thus eliminate a certain amount of power production, although the numerous small machines in use can only be driven economically by electric power. We are satisfied, however, that even the larger machines could not economically be driven by steam in a factory of the size under consideration and we there-

fore recommend that all machinery outside the boiler house and power plant should be electrically driven.

DESCRIPTION OF FACTORY FOR THE MANUFACTURE OF SULPHATE OF AMMONIA

Plant and equipment.

44. A complete factory for the production of sulphate of ammonia by the method we have recommended will contain various items of plant and equipment which can be considered under the following headings :—

1. *Production plants*
   (*a*) Ammonia plant.
   (*b*) Sulphate plant.
   (*c*) Product storage and packing.
2. *Service plants and equipment*
   (*a*) Boiler and power plants.
   (*b*) Water supply and cooling water systems.
   (*c*) Sundry services, comprising.
      (*i*) Raw material storage and handling.
      (*ii*) Waste product disposal.
      (*iii*) Minor services.
   (*d*) Laboratories, workshops, stores, etc., comprising
      (*i*) Laboratories.
      (*ii*) Workshops.
      (*iii*) Stores.
      (*iv*) Offices and canteens.
      (*v*) First-aid, fire and safety services.
   (*e*) Railways and roads.

Ammonia plant.

45. The ammonia plant may conveniently be divided into two sections, the gas plant in which the semi-water-gas is produced and the ammonia synthesis plant in which this gas is compressed, purified and finally converted into ammonia. These two sections will be housed in separate buildings.

Gas plant.

46. In the main gas plant building will be installed a number of gas generators which should be provided with fully automatic controls ; each generator should be equipped for raising steam from heat which would otherwise be lost. The raw gas will be washed by direct contact with water which will perform the dual function of cooling and cleaning the gas. Auxiliary machinery necessary on this plant will include air blowers, fans and a system, probably hydraulic, for the outomatic operation of the generators. As in the case of town's gas purification, the removal of the principal sulphur-containing impurity (hydrogen sulphide) from the gas will probably best be achieved by passing it through purifiers containing iron oxide.

Ammonia synthesis plant.

47. From the gas plant the gas will pass through a gas-holder, to act as a buffer and small-capacity storage, to the ammonia synthesis plant. Here the remaining processes in the manufacture of ammonia will be undertaken. The majority of the plant should be erected on structures in the open while the machinery and controls should be located in an adjoining building. The first stage in the process will consist in the conversion of the majority of the carbon monoxide

in the gas to carbon dioxide by passing the gass, mixed with steam, over a heated catalyst, the hydrogen content of the gas being simultaneously increased. It will then be necessary to purify the gas completely from carbon dioxide and carbon monoxide before the final synthesis of ammonia from the remaining nitrogen and hydrogen can take place. Since the gas will also require compressing to a high pressure for this purpose, it is advantageous to carry out the removal of the two impurities under pressure, chemical absorbents being circulated through suitable scrubbing towers to achieve this object. The carbon dioxide so removed will be recovered from solution for use in the conversion of ammonia to ammonium carbonate. The gas will be compressed by reciprocating gas compressors, preferably direct-driven by electric motors, to a pressure of 5,000 to 5,500 lbs. per square inch ; these machines will account for a large proportion of the total power consumption of the factory. The compressed and purified gas is finally circulated through high-pressure vessels containing heated catalyst, where the combination of hydrogen and nitrogen to ammonia takes place. The ammonia is then removed from the system and transferred to storage vessels

Sulphate plant.

48. The sulphate plant can also conveniently be divided into two sections each housed in a separate building. In the first, the gypsum will be crushed and ground to a sufficient fineness to enable it to react with the ammonium carbonate solution, the exact type of crushing and grinding plant to be installed being a matter of detailed design. In the second section of the plant the solution of ammonium carbonate will be prepared from the ammonia and carbon dioxide supplied by the ammonia plant, and into this solution the finely-ground gypsum will be mixed. The chemical change taking place results, as explained in paragraph 24, in the formation of ammonium sulphate, which remains in solution, and calcium carbonate or chalk, which is suspended in the form of finely divided, highly insoluble particles. This chalk must be separated from the solution by means of continuously operating filters and will be discharged in the form of a moist powder. The solution of ammonium sulphate will be crystallised in large steam-heated evaporators operating under partial vacuum, the crystals from the evaporator being dried in a gas-heated drier and carried by a conveyor to the product storage and packing section. Auxiliary equipment required will include vacuum pumps for the filters, scrubbers for recovery of ammonia and a considerable number of small pumps for handling the various solutions.

Product storage and packing.

49. The third of the production plants will consist of a silo or bulk store for sulphate of ammonia and a building housing the equipment for packing into bags. We recommend that the silo should be capable of storing a quantity of sulphate equivalent to at least three months' supply. Conveying equipment must be provided from the sulphate plant to this silo and from the silo to the packing plant. The packing plant should be equipped with bag-filling and weighing machines and sewing machines for closing the bags. The railway by which the finished product leaves the packing plant must run through the building in order that packing shall not be interrupted by inclement weather.

Boiler plant.

50. For factories in which power is generated, as indicated in paragraph 42, the boiler plant will raise steam at a pressure of approximately 600 lbs. per sq. inch and a total temperature of 800°F. For the larger size of plants, mechanical handling of

coal into the bunkers and of ash into disposal wagons is justified. Full provision should be made for softening and deaerating the feed water, part of which will consist of condensate returned from the process. The feed water will be heated by steam bled from a suitable stage or stages of the turbines. Feed water pumps should be duplicated, one set being driven by steam and the other by electric motors. In the case of smaller factories, in which power is not generated in the factory, the boiler plant would be simpler, boilers working at 150 lbs. per square inch being installed with simpler handling facilities for coal and ash.

Power plant.

51. In larger factories, where power is generated, electric generators driven by turbines passing out steam at about 15 lbs. per square inch gauge will be installed. It will probably prove economic to instal three identical generating sets, two being capable of taking care of the normal load. Power should be generated at a standard voltage (6,600 or 11,000 volts) suitable for driving large motors in the factory and, in fixing this voltage, consideration must be given to the external supply which has to be used to supplement the factory power station and to provide flexibility. The power plant will include switchgear for controlling the distribution of the power and of the incoming supply ; transformers for stepping down the voltage to a valve suitable for the smaller drives on the factory must be provided. Modern fire-fighting equipment such as a spray system for the generators and carbon dioxide supply to the switchgear are desirable and should be included. In factories where power is not generated, a distribution sub-station will be required, in which the imported power is distributed and transformers are provided for stepping down the voltage to that of the smaller motors.

Water supply and cooling systems.

52. The factory will require a reliable supply of clean water, which may either be taken from tube wells or from a river or canal, in which case purification plant will be needed. It should be emphasised that an absolutely certain and constant supply throughout the twenty four hours of the day for the whole of the year is essential. Water will be required in the factory for use as boiler feed, as a scrubbing medium in the ammonia and sulphate plants, to make up for losses from the cooling systems referred to below and for numerous minor uses. In addition, it will be used for drinking and washing purposes, both in the factory and in the housing estates, and chlorination of this supply will be essential. Both the ammonia plant and the sulphate plant require large quantities of cooling water. Considerable latitude is possible in designing the cooling water equipment, but broadly speaking it is true to say that, in the absence of a perennial silt-free river, the use of recirculation around cooling towers is the best system for the bulk of the cooling water requirements on account of the considerable saving in fresh water consumption. Canal water is unsuitable for most of the cooling water requirements unless a filtration plant is installed ; it could, however, be used advantageously without filtration, for a small proportion of the total requirement.

Raw material storage and handling.

53. We recommend that arrangements be made for the storage of not less than two months' supply of the three main raw materials required by the factory. This will necessitate the storage of 30,000 tons of coke, 40,000 tons of coal and 90.000 tons of gypsum. Owing to the high rate at

which these materials are used, it will be necessary to provide, in larger factories, mechanical handling from storage dumps and allowance has been made in our estimates for the provision of a system such as grabs and belt conveyors for use when drawing from stock.

Waste products' disposal.

54. The waste products from the factory consist of ash from the boilers and gas plant amounting to about 250 tons per day and chalk from the sulphate plant amounting to about 1,250 tons per day. Although some of the latter may be sold, as mentioned in paragraph 25, adequate arrangements will have to be made in a large factory for the mechanical handling of these waste products and transporting them from the plants to the dumps. It should be pointed out that a large area of ground must be set aside for this purpose since the waste chalk will alone amount to about ten million tons after twenty years' working.

Minor services.

55. There are several minor services which must be provided, exact details of which need not be specified until the final design of the plant is settled. Under this heading can conveniently be included the numerous pipes and conveyors connecting the various buildings and also the necessary internal road and rail transport vehicles. Amongst the minor services will be air-compressors to supply compressed air for various purposes to the different plants. It will also be necessary to arrange for a supply of nitrogen, obtained by burning waste gas from the ammonia plant, for the purpose of sweeping-out vessels full of inflammable gas or air. A supply of gas for heating purposes will also be required for the sulphate of ammonia driers, workshops and laboratories.

Laboratories.

56. Laboratories will have to be provided both for the control tests required at frequent intervals in the various stages of the process, for the control of the quality of raw materials and finished product and for various analytical purposes associated with a large chemical factory. Metallurgical tests and examinations will be necessary and bacteriological tests will no doubt have to be carried out on the water supply to the housing estate serving the factory. Moreover, there is always a certain amount of minor research work necessary into the day-to-day difficulties which occur in a chemical factory. These requirements will necessitate the provision of a well-equipped central laboratory and two or three smaller ones located at the plants which they serve. The main laboratory should be equipped for simple research work as well as for routine control and we strongly recommend that this laboratory should be air-conditioned. If a number of factories is built, a more elaborate laboratory should be included in one of them, since any research work undertaken can well be centralised.

Workshops.

57. First class workshop facilities are essential for factories of the type we envisage, and provision must be made for an up-to-date workshop equipped with the most modern machine tools and other plant and machinery suitable to undertake a wide range of repair and testing operations on the mechanical, electrical and chemical plant installed in the factory. A small drawing office will also be required to undertake the preparation of drawings and details of any alterations and additions which from time to time may be required.

Stores.

58. It will be necessary to provide stores for the safe keeping of the large assortment of engineering materials and spares required in the factory. On account of the specialised machinery which must be imported from overseas a very large

quantity of spare parts will be needed. Storage of the minor materials required in the process can also be conveniently arranged in the same building.

59. Main offices will have to be provided for housing the technical and clerical staff. The offices, like the laboratories, should in our opinion be air-conditioned in the interests of greater efficiency of working. We are of opinion that it would be good policy for a factory such as is under consideration here to provide facilities for all employees, staff and labour alike, to obtain suitable meals under proper conditions. Provision should therefore be made for the necessary number of canteens suitable to meet the needs of the different classes of communities employed.

Offices and canteens.

60. It will be necessary to provide an adequately staffed medical department for the factory as well as for the housing estate. Although the processes used in the manufacture of sulphate of ammonia are not especially dangerous, there are certain hazards due to the presence of poisonous gases, such as carbon monoxide and ammonia, which have to be guarded against and first-aid and medical consulting rooms will have to be provided. In view of the above-mentioned gas hazard, it is necessary to make provision for gas-masks and other anti-gas equipment both to guard against an unexpected escape of gas and for plant maintenance work on gas-containing pipes and vessels. Provision will therefore have to be made for a small store and repair shop for the efficient maintenance of these gas-masks and other equipment. The fire hazard in a sulphate of ammonia plant is not large and no special precautions need be taken beyond the provision of a small fire station and the usual fire-fighting equipment.

First-aid, fire and safety services.

61 The railway system of the factory is a service which will need careful designing in view of the large quantities of materials being handled. When on normal production the following quantities of material will enter or leave the plants in a single large factory :—

Railways and roads.

Boiler plant	..	..	700 tons per day coal.
Gas plant	..	..	500 tons per day coke.
Sulphate plant	..	..	1,500 tons per day gypsum.
Product packing up to		..	2,000 tons per day sulphate of ammonia.

The factory railway system must be designed to allow the full twenty-four-hour requirements of the plants being handled in the normal eight hour-working day. In addition to railways, an adequate road system must be provided.

STAFF AND LABOUR REQUIREMENTS

62. In considering the personnel necessary to operate a factory of the type recommended, it is advisable to deal separately with staff and labour. The term "staff" is assumed to comprise all employees of the factory whose remuneration is not calculated upon an hourly or daily basis, all others being included under the heading "labour". The staff can conveniently be divided into the following categories :—

Staff.

(*i*) Technical staff ;
(*ii*) Non-technical staff ;
(*iii*) Foremen.

63. The technical staff will consist of the senior administrative staff, subordinate to whom will be the general technical staff in charge of the various sections of the plant for both running and repairs. For a single factory of 350,000 tons per annum the administrative staff will consist of a Superintendent, a Works Manager and a Works Engineer, the two latter each requiring an assistant or deputy. The Superintendent. Works Manager and Works Engineer should be men with high academic qualifications, with considerable experience of administrative work in chemical factories and capable of managing a large staff both technical and non-technical. The two assistants or deputies should be men of the same type and training but may possess less administrative experience ; they should however be suitable for ultimate promotion to the position occupied by their superiors. The remainder of the technical staff will consist of chemists, engineers and draftsmen. The chemists will be in charge of the various individual units making up the factory, *i.e.*, the gas plant, the boiler plant, the ammonia synthesis plant, the sulphate plant and the laboratories, whilst the engineers will be responsible for the maintenance and repair of the above sections of the plant and for running the workshops. In addition it will be necessary to retain a civil engineer and an electrical engineer. It is estimated that a single large plant will require six chemists, six engineers and two draftsmen. The chemists and engineers should be men with good University training, possessing practical experience in chemical technology. For factories with smaller outputs, this number will be less but by no means in proportion to the reduction in output, as will be apparent from the Table in paragraph 66.

Technical staff.

64. The non-technical staff may be divided into the senior non-technical staff and the junior clerical staff. The first sub-division will include the staff in charge of office organisation, labour, the housing estate, stores accounts department, etc., and included in this category will be a medical officer. The junior clerical staff will consist of general clerks, stenographers, time-keepers, pay clerks costing clerks, etc. The number in this class is difficult to estimate precisely until it is decided to what extent such items as costing and accounting are controlled within the factory or by some outside department. Considerable variation in the numbers given, however, will not materially affect the cost of production of sulphate of ammonia.

Non-technical staff.

65. In view of the complicated technical operations involved in the production of sulphate of ammonia, a large number of foremen of grades from principal foreman to assistant foreman will be required. Their duties will be as follows :—

Foremen.

(*i*) Controlling the process and supervising the labour throughout the twenty-four hours.

(*ii*) Supervising the repair and maintenance of the factory and the running of the workshops.

(*iii*) Supervising various ancillary operations including laboratory work, the control and repair of instruments and the control of transport and traffic.

66 The table at the end of this paragraph gives details of the numbers of the three categories of staff required for various schemes of production of the 350 000 tons of sulphate of ammonia per annum. It must be emphasised that these figures have only been determined with sufficient accuracy for the purpose under consideration, namely, to " calculate the approximate cost of operations and production

Numbers of staff required.

of finished sulphate of ammonia.''. Greater detail and accuracy is not only unnecessary but impracticable at this stage when exact details of the plants and layouts are not determined. When the final design and details of a factory are prepared by the contractors who will undertake the work, it will then be possible to specify exact numbers of staff, but small divergences from the figures we have calculated will not materially affect the total cost of production. Moreover, the numbers of technical staff which we have estimated are sufficiently accurate to permit the necessary training schemes to be initiated.

Staff requirements

Production scheme.	Numbers of staff employed.			
	Technical.	Non-technical.	Foremen.	Total.
One factory of 100,000 and five, each of 50,000 tons per annum output.	75	286	114	475
Three factories each of 116,700 tons per annum output.	45	198	72	315
One factory of 250,000 and one of 100,000 tons per annum output.	32	153	50	235
One factory of 350,000 tons per annum output	19	108	28	155

Training of staff.

67. The training of technical staff for a factory of the type recommended is a matter which requires most careful consideration. It is assumed that the erection of the factory will be in the hands of a main contractor who will be under obligation to provide a number of technicians for this purpose. The contractor should also be made responsible for supervising the starting of the factory and its operation for a period of a few months until the specified output has been demonstrated and the plant as a whole is entirely satisfactory and fit to be handed over to the permanent staff. We recommend that a few senior technicians, should be retained in a consultative capacity for an extended period, during which the factory will be entirely controlled and operated by its own permanent staff.

68. There now arises the question as to the best method of training Indian nationals to assist the specialists who will be provided for the initial supervision and to take over from them entire responsibility in the shortest possible time. We suggest that the majority of technical staff should be on the site to watch the erection of the plant soon after the preparatory stage of site development, foundation and building work is complete. They will thus acquire a first-hand knowledge of the special types of plant and machinery installed and be ready to take an active part, under the supervision of specialists, in the starting operations. It will however, be necessary for a majority of the technical staff to receive training prior to this in a factory of the type proposed and we are of opinion that this can best be carried out by sending a number of carefully selected Indians to undergo a course of training overseas. It is therefore recommended that as soon as the contract for the erection of the factory has been negotiated, a number of Indian chemists and engineers with good University qualifications and with sound industrial experience in some of the chemical works of ordnance

factories in this country should be selected and sent overseas for a course of training. It cannot be too strongly emphasised that this training must be of a thoroughly practical character since at the start of the plant the staff must be prepared, not only to supervise, but to carry out with their own hands for instructional purposes any of the operations, as the workmen will be completely new to this type of work. We are confident that there will be no difficulty in arranging with the successful contractor for a course of practical training to be given to those Indian members of the staff who may be selected for this purpose.

Labour.

69. The labour, that is to say all men below the rank of assistant foreman, required, for a factory of the type recommended can conveniently be divided into the following categories :—

(*i*) Process workers ;
(*ii*) Maintenance workers ;
(*iii*) General workers.

Process workers.

70. Process workers are the men required to work the plant and to operate the various types of machines. The class of man required for this duty will range from the manual labourer to the man capable of following simple written instructions and writing a short account of his work : it will include such men as boiler, turbine, compressor and pump attendants. In general, the majority must be capable of reading gauges and simple instruments and recording the figures read. In all probability two grades of supervisory rank will be required between the ordinary process worker and the assistant foreman, and these will, of course, receive higher rates of pay than their subordinates. It may be found advisable to adopt slightly different rates of pay for various grades of process worker. but this is a matter which can be left for detailed consideration when the final design of the plant is settled.

Maintenance workers.

71. The men necessary to carry out the maintenance, repair and minor modification work on the plants will be the skilled artisans and their helpers. This category will therefore include such men as fitters, electricians, welders, burners and plumbers, together with the men employed in the workshops, who will include turners, machinists, smiths, joiners and sheet metal workers. It will be very necessary to employ highly skilled men in this class, as many of the machines are complex and require the very highest workmanship in their repair, while at intervals the complete stripping and rebuilding of many of the machines will have to be undertaken. We feel that this matter cannot be too strongly emphasised and suggest that every effort should be made to provide continuity of employment and to establish a training scheme, analogous to apprenticeship to ensure an adequate and continuous supply of skilled workers.

General workers.

72. Under the heading of general workers is included all the unskilled labour required for the handling of materials together with all the men required about a factory for cleaning, gate keeping and similar duties. The number employed in this category is difficult to estimate, particularly since the numbers required for handling materials are dependent upon the extent to which mechanical handling devices are adopted ; even a considerable divergence however from the figures used for our estimate of cost will have but a small effect on the final cost of production of sulphate of ammonia.

73. Estimates have been prepared of the numbers of men required in the three categories for schemes of production involving factories of various sizes and are summarised in the table below :—

Numbers of men required.

Labour requirements.

Number and size of factories.	Numbers of men employed.			
	Process workers.	Maintenance workers.	General workers.	Total.
One factory of 100,000 and five, each of 50,000 tons per annum output.	1,310	1,882	887	4,079
Three factories each of 116,700 tons per annum output.	936	1,425	801	3,162
One factory of 250,000 and one of 100,000 tons per annum output.	768	1,200	787	2,755
One factory of 350,000 tons per annum output ..	572	936	775	2,283

74. The numbers given in the above table include sufficient reserves to allow for normal absence from work due to sickness and other causes. It has, however, been brought to our notice that seasonal absenteeism may occur in India on a large scale due to the workers assisting in agricultural duties at certain seasons. It will be very necesary to avoid such absenteeism in the factories under consideration and suitable measures should be adopted in furtherance of this object. The most important of these are the provision of good housing in the vicinity of the factory, the careful selection of workers and payment of good wages. The provision of a medical service will also result in a reduction of absenteeism due to sickness.

Absenteeism.

75. The table in paragraph 73 shows that approximately 2,300 to 4,000 men will be engaged in operating and maintaining the factory or factories ; of this total, almost all process workers will require special training in their duties. When it is remembered that most sections of the processes have to be controlled according to the readings of various gauges and meters, it will be appreciated that this training. especially for the type of worker with no previous industrial experience, requires careful attention. It will be possible however in the period before production commences, to select suitable candidates and to ensure that they are capable of taking appropriate action when certain instrument readings are noted. Further training during initial operation of the factory will be given by foremen and other supervisors and by a limited number of experienced men brought from overseas for the training period. It should be recognised that the training must be thorough, since, with a system of continuously operating successive processes, mal-operation on the part of a single workman in one section can result in disorganisation of a large proportion of the work of the factory. It

Training of labour.

is therefore recommended that steps should be taken to select candidates for training several months before the factory goes into operation, especial importance being attached to intelligence and reliability in making the selection.

76. The training of the workers who are occupied with maintenance work should not be so difficult, since it is assumed that skilled artisans will be available in the numbers required, and they will merely need to adapt their previously-gained knowledge and experience to the particular jobs arising in the factory. Nevertheless, since there are several types of work which are outside the normal range of engineering practice and are not even encountered in most chemical factories, some specialised training will be required. Many opportunities for such training will present themselves when the factory is under construction, during which period it will also be possible to select men who show sufficient ability and aptitude to be regarded as worthy of permanent retention. In the case of skilled workers, it will also be advisable to import a few men experienced in carrying out repair work in chemical factories of this particular type, who will be able to give instruction in safe methods of working on plant used for proceessing gasses, and corrosive chemicals. It will be necessary to obtain the services of one man who is conversant with all the modern safety appliances employed in this type of work, who is capable of training men in their use and is able to overhaul the apparatus and keep it in order.

SCHEMES OF PRODUCTION

Allocation of the product.

77. The allocation of the proposed 350,000 tons per annum of sulphate of ammonia throughout the country is obviously of fundamental importance in determining the location of factories. This subject has been examined by the Department of Education, Health and Lands, the Department of Food and the Department of Supply and we have been advised that, for the purpose of our investigation and report, the country as a whole should be divided into the following consuming regions :—

		Tons per annum
Region 1.	North East India (Eastern Bihar, Bengal Assam and Orissa)	100,000
Region 2.	Central East India (Western Bihar, Eastern half United Provinces and Central Provinces)	50,000
Region 3.	North West India (Western half United Provinces, Punjab and North-West-Frontier Province)	50,000
Region 4.	West India (Bombay, Sind, Baroda, etc.)	50,000
Region 5.	South India (Madras, Hyderabad, Mysore, etc.)—	
	(*a*) Cauveri area	50,000
	(*b*) Godavari area	50,000
	Total ..	350,000

The cost of sulphate of ammonia when it arrives in the hands of the consumer can be considered to be made up of the following three components :—

(*i*) *The factory cost, i.e.,* the total cost of production at the factory including capital and other charges ;

(*ii*) *The primary distribution cost, i.e.,* the cost of transporting the product from the factory to a number of principal depots in the consuming regions ;

(*iii*) *The secondary distribution cost, i.e.,* the cost of distributing the material from the depots to the consumers.

In order to compare the economics of manufacture of sulphate of ammonia in different parts of India, it will be necessary to calculate the factory cost and the primary distribution cost but not the secondary distribution cost, since the latter will be common to all schemes of production. When detailed schemes of distribution throughout the country are prepared, it will undoubtedly be found desirable to have a number of depots in each of the main consuming regions and to arrive at accurate primary distribution costs it will be necessary to know the exact number and locations of these depots. These cannot be determind at present since detailed schemes of distribution have not yet been evolved and the necessary basis for calculation is not available ; we are satisfied however that no appreciable error will be introduced if it is assumed that each can be served by one central depot. For the purpose of simplifying the comparisons, we have chosen for these regional depots sites which would be suitable for locating a factory capable of meeting the regional demand.

Regional depots and production centres.

78. Taking the above factors into consideration, we are of opinion that reasonable localities to choose for each region, in which a possible factory might be sited and which will also serve for a hypothetical regional distribution depot, are as follows :—

	Locality.
1. North East India (Eastern Bihar, Bengal, Assam and Orissa) ..	Dhanbad.
2. Central East India (Western Bihar, Eastern half United Provinces and Central Provinces)	Moghal Sarai.
3. North West India (Western half United Provinces, Punjab, and North-West Frontier Province)	Amritsar.
4. West India (Bombay, Sind, Baroda, etc.)	Bombay.
5. South India (Madras, Hyderabad, Mysore, etc.)—	
(*a*) Cauveri area	Trichinopoly.
(*b*) Godavari area	Bezwada.

Factors controlling the location of factories.

79. When choosing suitable locations for chemical works, a large number of factors has to be taken into consideration, such as availability of raw materials, distance from consuming centres, transport facilities, availability of electric power, water, labour and suitable sites for buildings. The first two of these factors are the most important for a project of the magnitude of the present scheme and for a country of the size of India. As has been shown, the availability of electric power is not of great importance for a large factory, as the combination of a power station and boiler plant for process steam leads to great economies, whilst the remaining requirements, such as water, labour and suitable sites, can usually be satisfied. Availability of raw materials and proximity to markets for the finished products are therefore, the factors which must be given primary attention. Since the sources of the raw materials in India are extremely localised, whilst the demand for the finished product is widely spread, it is clear that two methods of approach to the problem of the manufacture of sulphate of ammonia in India should be examined ; in the first, sulphate of ammonia is produced in each of the main consuming regions and in the second,

in a smaller number of centralised factories. We therefore proceed to consider briefly certain general arguments concerning the relative merits of the two methods.

80. The weight of raw materials required for the selected process amounts to some two and three-quarter times that of the finished product, and it is clear, therefore, that transport of raw materials will have a more important influence on the economics of production than transport of the product. Having regard to the sources of the three principal raw materials, this factor is an important argument in favour of centralisation, as will be more clearly apparent at a later stage when results of the detailed cost calculations have been given. Furthermore, when the urgency of the need for fertilisers is kept in mind. another disadvantage of decentralisation becomes apparent ; erection of all the factories would have to be carried on simultaneously and the dispersal of effort resulting in building a number of small units would be uneconomic. Again, the staffing and supervision of a large number of small factories is a matter which can in no way be overlooked. An increase in the number of factories increases the difficulty of training a sufficient number of men to become officers in the factories and it cannot be too strongly emphasised that the number of experienced staff necessary to run the type of factory under discussion would in no way be reduced proportionately to the reduction in output of the smaller factory. The concentration of all the production for the country at one point is also not without its disadvantages, since such troubles as labour disputes or interruption of transport might lead to the cessation of the whole output instead of only a part, as would be the case if output were spread over a number of factories. This difficulty is not so serious as might be supposed and if the site is carefully chosen, should be negligible ; furthermore, the provision of stocks in regional depots will safeguard the consumer.

81. From the preceding paragraph it will be apparent that many schemes 'or the production of the 350,000 tons per annum of sulphate of ammonia can be formulated. The scheme which will be most economic in capital cost will nvolve a single factory, whilst the scheme with the lowest freight cost on the inished product will require a factory in each consuming region. Between hese two extremes, a number of schemes can be put forward, each resulting in . different compromise between capital charges and freight on product. It is iot possible, however, within the terms of reference given to the Mission to select he most economic method of manufacture solely on the basis of general argunents ; for this purpose, estimates of the relevant capital and production costs nust be prepared. It is necessary to consider at the outset to what extent dispersal of production of 350,000 tons per annum should be carried. Taking into ccount the distribution of the product as set out in paragraph 77 and in view of he fact that a total production of 350,000 tons per annum is required, we have oncluded that in no case should a factory of less than 50,000 tons per annum e considered.

cheme for six factories.

82. Starting with the proposal to manufacture sulphate of ammonia at a factory located in each consuming region, estimates of capital and production costs, details of which re given in Annexures B and C, have been prepared for six factories each situted in one of the localities mentioned in paragraph 78. This scheme will require ve factories of the size we have taken as the smallest permissible production nit (50,000 tons per annum) and one of twice this size (100,000 tons per annum).

The estimated total capital cost of this scheme including the capital necessary for the housing estates is Rs. 21 crores and the average production cost is estimated to be Rs. 167 per ton at the factory. Since each factory is located in its own consuming region, no primary distribution charge has to be added to this cost of production.

Scheme for three factories.

83. It is now necessary to consider what economies can be achieved by a certain amount of concentration of production and for this purpose a scheme involving the sub-division of the total 350,000 tons per annum into three factories each producing 116,700 tons per annum has been considered, as it can readily be understood that appreciable savings in design and fabrication can be effected by selecting three factories of equal size. A study of the regional allocation of consumption leads to the siting of one of the three factories in the north east, one in the north west and one in the south ; for the purpose of this estimate, sites in the neighbourhood of Dhanbad, Aligarh and Trichinopoly have been assumed. For this scheme, the capital involved amounts to approximately Rs. 16 crores in all, and the factory production cost is estimated at Rs. 139 per ton. Since part of the product from these factories have to be railed to the points which we have chosen as regional distribution centres, it is necessary to add to this factory cost an average charge for the freight on the finished product thus arriving at an average depot cost of Rs. 144 per ton. It is at once apparent that this scheme of production is more attractive, both in capital and production costs, than the scheme for six factories.

Scheme for two factories.

84. The above conclusion at once suggests that further economies might be effected by reducing the number of factories to two, one in the south, where 100,000 tons per annum is required and one in the north for the remaining 250,000 tons. For this scheme the capital cost is estimated to be approximately Rs. 13 crores and the average production cost Rs. 135 per ton delivered at the regional depots.

Scheme for a single factory.

85. The final scheme for consideration is that in which all production is centralised in one factory and for this scheme it is necessary to consider in somewhat greater detail the question of exact location. This matter is dealt with in the succeeding paragraphs but, anticipating the conclusions there recorded, it may be stated that the capital cost of a single factory, in the most favourable location (near Aligarh), is estimated to be Rs. 10.1 crores, whilst the estimated factory cost is Rs. 114 and the average depot cost Rs. 126 per ton. The costs of the above schemes are summarised in the following table.

Summary of estimated capital and production cost

Production scheme.	Capital Costs Rs. crores.	Cost of Product Rs. per ton.	
		At factory.	At depot.
Five factories each of 50,000 tons per year and one of 100,000 tons per year.	21·0	167	167
Three factories each of 116,700 tons per year ..	15·7	139	144
One factory of 250,000 tons per year and one of 100,000 tons per year.	12·7	127	135
One factory of 350,000 tons per year	10·1	114	126

86. From a consideration of the figures we have given, it is obvious that the scheme to be recommended is one in which the whole of the production is concentrated in a single factory, since in the others the very much higher capital charges together with greater raw material freights and the higher wages and supervision more than outweigh the cost of carriage on the finished product. When other factors, such as the smaller number of technical staff required both for construction and operation of a single factory and the probability of an earlier attainment of full production are taken into consideration, the case in favour of the single factory is overwhelmingly great. We have no hesitation, therefore, in recommending that the most economic method of manufacturing 350,000 tons per annum of sulphate of ammonia in India is to centralise production in a single factory.

Scheme recommended.

87. It is now desirable to consider in greater detail the best location for the single factory. It has been shown in paragraphs 35 and 37 that, of the three principal raw materials required for the manufacture of sulphate of ammonia, coke is best obtained from the Bihar coalfields and gypsum from the Punjab and Rajputana. Coal would be obtained from the nearest large coalfield which, in the case of a factory located between the above sources of coke and gypsum, would probably also be the Bihar coalfields. It is unfortunate from the country's point of view that this wide separation of the raw materials should exist, but, on the other hand, the greater part of the intervening distance is covered by the best developed system of railway communications in India, and the heavy volume of traffic necessitated by the concentration of production in one unit should be handled by this railway system without difficulty. If the probable distribution of the product given in paragraph 77 be examined, and the fact that the weight of raw materials to be moved is approximately two and three-quarter times that of the finished product be kept in mind, it will be seen that a single unit can, in fact, be advantageously located at some point along a line between Bihar and the Punjab, provided that the location chosen is not too far to the north west. Location of a factory at a point in the north west, though involving less total freight on raw materials, would result in excessive freight on the product, of which the greater portion is consumed in the eastern half of the country. It is concluded therefore that, generally speaking, the factory should be located in the Gangetic plain. Further, the economics of production will not be seriously affected by the precise position of the factory within the limits suggested. The problem is therefore resolved into examining the advantages and disadvantages of various possible sites, giving weight to such factors as transport, provision of water supply, availability of labour, proximity to existing electric supply systems and choice of land suitable for development.

Location of the single factory.

88. One general aspect of the question may be briefly discussed at this point—the desirability or otherwise of placing the factory in close proximity to an existing town or city which would be capable of housing the factory labour, this scheme having the advantage of reducing the capital expenditure necessary for housing. During the course of our tour, however, we were strongly impressed with the advantages to be gained from providing housing for the majority of the factory workers, not only with the object of avoiding turnover of labour, which in most cases will require an appreciable period of training, but also for the purpose of providing

Location of factory near a city.

surroundings more conducive to health and well-being than exist in the conditions of overcrowding found in most cities. It is concluded therefore that no attempt should be made on grounds of economy in housing to locate the factory near an existing centre of population.

Site for a factory in Bihar or United Provinces.

89. The number of possible factory sites in the area defined above is obviously large but, to avoid excessive discussion, it may be stated that after consultation with the Provincial Governments concerned, we have been led to examine in more detail two sites, one situated at Sindri on the river Damodar near Dhanbad in Bihar, and the other at Harduaganj near Aligarh in the United Provinces. A choice has therefore to be made between these two sites.

Advantages of Sindri near Dhanbad.

90. The advantages of locating the factory at Sindri may be summarised as follows:—

(*i*) A factory in the Bihar coalfield will be able to take advantage of the flow of empty coal and coke wagons returning to the collieries for bringing in its supply of gypsum. This would unquestionably lead to some economy in the operation of the railway system although it is difficult to put a precise value on this item.

(*ii*) It is obvious that the total movement of raw materials to a factory will be the same wherever the factory is located on a railway joining the sources of raw materials. In the case of the factory situated at Sindri, at the source of two of the raw materials, the movement of the other raw material will, broadly speaking, involve a single long haul in place of the shorter ones necessitated for all the raw materials to a factory situated elsewhere. It is preferable from the point of view of the railway to cater for a single long hand although here again it is difficult to translate this into actual cost figures.

(*iii*) From the point of view of the distribution of the sulphate of ammonia, it will be seen that Sindri is slightly the better centre for this purpose and figures given in Annexure C show an advantage of Rs. 2.2 per ton in favour of this site.

(*iv*) A general point in favour of locating a factory for the manufacture of sulphate of ammonia in a coalfield arises from the fact that it would then be better able to take advantage of any developments in utilisation of low grade fuel than a factory situated at a distance from the coalfield, since at the latter the freight charges on the useless constituents of a low grade fuel would render it less attractive.

Advantages of Harduaganj near Aligarh.

91. The advantages of locating the factory at Harduaganj may be summarised as follows:—

(*i*) A strong argument in favour of this site is the greater simplicity and certainty of arranging a water supply. At Sindri the only available source of water supply is the River Damodar. The vagaries of this notoriously difficult river need no emphasis and would certainly involve considerable expenditure to provide against flood damage on the one hand and shortage of water during the dry weather on the other. By the courtesy of the Directors of the Tata Iron and Steel Co. Ltd., and of the Steel Corporation of Bengal, Ltd. an inspection was made of the large pumping and filtration plants of these concerns,

situated on the Subarnarekha and Damodar rivers respectively. During these visits, full information was placed at our disposal and the problems involved were discussed with the officials concerned. For Harduaganj, on the other hand, there is strong evidence, supplied by the Irrigation Engineers of the Province and based on measurements carried out over a period, that the water requirements of the factory can be supplied by a comparatively inexpensive system of tube-wells. It is understood that the Sindri site is not favourable for tube-well sinking, and in any case reliance on this source of water could not be justified in the absence of statistics for actual wells in the district.

(*ii*) In favour of Harduaganj is the fact that there already exist in the area selected two large buildings which, although they would not be suitable for use as any of the plant buildings, would be useful for a number of minor purposes and invaluable during the construction period.

(*iii*) The site at Harduaganj is more level than any possible site at Sindri, and this will involve much less development work, a factor which will have a considerable bearing on the total time of construction of the factory.

(*iv*) Railway access already exists at Harduaganj whilst at Sindri it would be necessary to build a railway siding of some five miles in length to link the site with the nearest main line.

(*v*) The above items will result in a substantial difference in capital cost which we estimate at Rs. 41 lakhs in favour of Harduaganj; this will be reflected in the production cost to the extent of Rs. 0·8 per ton.

(*vi*) There already exists at Harduaganj a thermal power station capable of supplying the small amount of external power required by the fertiliser factory whilst at Sindri such a station is at present only projected. We have, however, assumed that this projected station (part of the Bihar Grid Scheme) would be in production within a reasonable time of starting a factory at Sindri and that during the interim period alternative arrangements could be made. Equality is therefore assumed in the matter of electric supply at the two sites, although the existing supply at Harduaganj would facilitate the construction of the factory there and any delay in the completion of the Bihar Grid Station at Sindri would possibly delay the date of achievement of full production in a fertiliser factory at that place.

(*vii*) Since Harduaganj is nearer the sources of gypsum there is an advantage in freight charges on raw materials amounting to Rs. 4·5 per ton.

Site recommended.

92. On balance therefore the arguments favour Harduaganj, which we recommend as the site for the fertiliser factory in preference to Sindri on the grounds that the capital cost will be lower by Rs. 41 lakhs, the production cost lower by Rs. 3.1 per ton of product, the water supply more assured and the factory ready for operation at an earlier date.

ESTIMATES OF CAPITAL COST OF SULPHATE OF AMMONIA FACTORIES.

Introduction.

93. Estimates of the approximate capital costs of factories for the production of sulphate of ammonia of outputs varying from 50,000 to 350,000 tons per annum are given in Annexure B, Part I. It will suffice for the purpose of this Report if we discuss the estimate amounting to Rs. 10·1 crores for the single factory producing 350,000 tons of sulphate of ammonia per annum which we have recommended should be adopted and explain briefly the general basis on which it has been framed. In paragraph 44 we indicated the plant, equipment and services required for a sulphate of ammonia factory and in the subsequent paragraphs we fully described these requirements. The estimate of the approximate capital cost of a single factory located at Harduaganj is as follows:—

	Rs.
1. *Production plants.*	
(a) Ammonia plant	2,62,50,000
(b) Sulphate plant	2,10,50,000
(c) Product storage and packing	50,50,000
2. *Service plants and equipment.*	
(a) Boiler and power plants	1,98,50,000
(b) Water supply and cooling water systems	45,00,000
(c) Sundry services	92,50,000
(d) Laboratories, workshops, stores, etc.	15,00,000
(e) Railways and roads	14,00,000
(f) Land purchase, surveys and drainage	6,00,000
3. *Stocks of materials and starting expenses*	50,00,000
4. *Housing estate including land purchase and hospital* ..	67,50,000
	10,12,00,000

Basis of estimates.

94. It will readily be appreciated that the estimate of the capital cost of the factory recommended has been prepared at a time when prices and market conditions are unstable. The estimates have been prepared on the basis of conditions existing at present and no attempt has been made to forecast the trend of future changes in price levels. The cost shown against each head of the estimate has been based on the best information we have been able to obtain in the case of plant and equipment which have to be imported from abroad, we have estimated ocean and rail freights and port dues at current public rates and customs duty has been calculated at an average rate of 12½ per cent. *ad valorem* on the c.i.f. value; no allowance, however, has been made in our estimates to cover war risk insurance. Our estimates for the cost of the production plants, boiler and power plants and services include in each case the cost of foundations, buildings, structures, plant and machinery, together with transport charges, erection and the appropriate proportion of the engineering design and supervision charges. Since the factory will operate continuously for twenty four hours per day throughout the year, adequate provision for standby plant is necessary and has been made

Technical supervision.

95. Provision has been made, in the appropriate items of the estimate, for adequate technical supervision during the construction and starting of the factory. It will be necessary to obtain from overseas a number of specialist engineers and chemists who possess experience in the construction and operation of a large fertiliser factory. We have assumed that overseas specialists will only be required for a comparatively short period and that their duties will comprise supervision of the construction from the commencement of work on the site, starting up of the processes and running the factory until it is in beneficial production. We have also provided for two senior specialists to be retained for a period of a further year to act as advisers. We have elsewhere recommended that a number of suitably qualified Indian technicians should be sent overseas for training as soon as contracts for the plant and equipment have been settled. The estimate does not provide for the expenditure which the acceptance of this recommendation will involve as we assume that the department of the Government responsible for technical training overseas will meet this expenditure from a separate grant.

Capital cost of mining plant.

96. We may here explain that the estimated cost of the factory, namely, Rs. 10·1 crores, does not include any capital expenditure which may be required for gypsum or anhydrite mining or quarrying operations. In the estimates of cost of production of sulphate of ammonia, the cost of gypsum includes an allowance to cover the appropriate charges on the estimated capital expenditure required for these operations.

Water supply and cooling water systems.

97. Under this head is included the equipment needed to make available and distribute the quantity of water required for the factory and its community, together with filtration plant where necessary. Provision has also been made for the cooling water systems for the gas, ammonia and sulphate plants, each comprising a coooling tower, pumps and circulating water mains.

Sundry services.

98. Provision has been made under this heading for raw material storage and handling, waste products disposal and such minor services as inter-connecting pipes, electrical distribution, lighting, compressed air and nitrogen supply.

Laboratories, workshops and stores.

99. The estimated expenditure under this head also covers the provision of offices, canteens and first-aid, fire and safety services. In paragraphs 59 and 60 we have explained in greater detail the requirements under these heads.

Railways and roads.

100. Adequate allowance has been provided for the first class system of railway reception and distribution sidings needed within the factory area to deal with the large quantities of materials to be handled—see paragraph 61—and to serve the different plants of the factory; this will be located on an existing broad gauge railway line and therefore no provision has been made for any railway requirements outside the factory area. Road access, particularly during the construction period, is also important and it is expected that the authority responsible will ensure that roads connecting the main road to the factory are suitable for heavy traffic; the amount included in the estimate is sufficient to cover the cost of roads within the factory area.

Land purchase, surveys and drainage.

101. Under this head, provision is made for the purchase of land for the factory together with cost of surveys and all expenditure required for the preparation of the site and drainage. We have assumed that reasonably good ground will be available and that no abnormal difficulties involving heavy expenditure will be encountered. We are satisfied from our inspection of the site and from the assurances we have received from the officials who are familiar with the neighbourhood that these conditions are fulfilled at Harduaganj.

Stocks of materials and starting expenses.

102. In the estimate of capital cost provision is made for stocks of raw materials and for disbursements during the period of non-productive operation. The amount included is equivalent to a consumption of materials based on two months' operation at full output, together with salaries, wages and other charges which have to be met during the starting period.

Housing estate.

103. We have already emphasised the importance of providing suitable living accommodation in close proximity to the factory, particularly for the specialists and key workers. In the estimates we have assumed that the number of permanent quarters required for the staff and workmen will be at least 155 and 1,700 respectively, and that in addition a number of temporary quarters will be required to accommodate the overseas personnel and specialists employed during the construction period and the early days of operation. An adequately equipped hospital will be necessary to deal with cases of sickness and accident. The total estimated cost of the housing estate including the cost of land acquisition amounts to Rs. 67·5 lakhs. We have included this expenditure as part of the capital cost of the factory but it might reasonably be held to be expenditure incurred for the improvement of the conditions of the community and should be defrayed from a grant assigned to that special purpose.

Construction plant and workshop tools.

104. We have made adequate provision in our estimate of capital cost for the tools and plant required for construction and also the machine tools for the workshop. We understand that a wide range of construction plant may be available for transfer from other projects nearing completion and that owing to reduction in manufacturing programmes many machine tools suitable for the factory workshop will be surplus to present requirements. Any construction plant and tools which can be obtained from these sources will be of great assistance and will facilitate early commencement of the construction work.

ALLOCATION OF CAPITAL EXPENDITURE BETWEEN INDIA AND ABROAD

Engineering manufacturing capacity in India.

105. We are required by our terms of reference to "estimate the amount and approximate value of plant, which it will be necessary to import from outside India, making the fullest possible use of materials and labour available in India." To obtain first hand knowledge of the capabilities of the engineering industry in India for the fabrication and manufacture of the various items of the plant required for the proposed factory, we inspected the works

of a number of the larger firms engaged in the manufacture of structural work, engineering plant and equipment. A list of works inspected is given in Statement III and from these visits and our discussions with the representatives whom we interviewed we are satisfied that there exists substantial manufacturing capacity of the type which can be utilised for the manufacture of certain items of the plant required for the factory. At present, however, practically the whole of this capacity is absorbed in munitions production and other essential war work, and our estimate of the amount and approximate value of plant which can be manufactured here can therefore only be regarded as an indication of India's potential capacity for the work under consideration. When the project has been approved and the work taken in hand, careful examination of the manufacturing position, in consultation with engineering and other interests, will be necessary to determine how much of the work can be undertaken in India in the light of any other commitments which then exist. From our investigations of the potential manufacturing capacity we consider that the supply of the plant and equipment could be allocated between India and abroad as follows:—

Plant and equipment to be obtained in India—

Structural steel work and buildings complete
Mild steel constructional work, such as tanks, vessels, low pressure gas and air mains
Gas holders and purifiers
Cranes
Cast iron water mains
Cast iron tanks and vessels
A proportion of the mechanical equipment
Refractory materials

Plant and equipment to be imported—

High pressure forgings, fittings and pipe work
High pressure compressors, pumps and circulators
Pumps, blowers and fans
Electrical equipment
Valves and instruments
High pressure, boiler quality and stainless steel constructional work
Tubes
Steam mains and fittings
Machinery of existing proprietary designs and in which special materials are incorporated
Insulation

Allocation of expenditure between India and abroad.

106. In Annexure B, Part II, we have allocated the total estimated expenditure on the project, amounting to Rs. 10·1 crores, between India and abroad. The allocation has been based on the capacity of India for the manufacture of certain items of plant and equipment which we have discussed in the preceding paragraph and we have assumed that as large a share as possible of the potential capacity of India will be made available for the manufacture

of these items; we have also indicated in detail in this estimate all expenditure, other than that on plant and equipment, which will be incurred in India. Our estimated allocation of expenditure is Rs. 6·0 crores in India and Rs. 4·1 crores abroad.

ESTIMATED COST OF PRODUCTION OF SULPHATE OF AMMONIA.

107. The estimated cost of production of sulphate of ammonia can conveniently be considered under the following heads:—

1. *The works cost* which will include the cost of:
   - (*a*) Principal raw materials
   - (*b*) Other materials required for process and repairs
   - (*c*) Labour and supervision
   - (*d*) Purchased electric power
   - (*e*) Packing materials
2. *The overhead charges* which will include:
   - (*a*) Interest on capital (Factory)
   - (*b*) Depreciation (Factory)
   - (*c*) Housing estate overheads

In the following paragraphs we shall briefly discuss these items and indicate how we have arrived at our estimate of cost of production.

Cost of raw materials.

108. The principal raw materials with which we are concerned are coal, coke and either gypsum or anhydrite; the quantities required to produce one ton of sulphate of ammonia are estimated to be as follows:—

Coal ..	..	..	0·71 ton (12,000 B. Th. U. per lb. nett)
Coke ..	..	..	0·51 ton (75% fixed carbon)
Gypsum	..	..	1·53 ton (93% purity)
Anhydrite	..	..	1.22 tons (92% purity)

The costs of these raw materials on which we have based our estimates of the cost of production include in each case the price at the source and the railway freight from the source to the factory. It will be necessary to discuss in some detail the choice of sources of gypsum and anhydrite and the cost of these materials, neither of which is at present produced in the quantities required.

Cost of coal and coke.

109. The figure given for coal applies to factories of productive capacities from 100,000 to 350,000 tons per annum of sulphate of ammonia in which power is generated within the factory. In factories of 50,000 tons per annum capacity, in which all power is purchased from a power supply system, outside the factory an estimated coal consumption of 0·66 tons per ton of sulphate is taken; the decrease in coal

consumption is not as large as might be expected, due to the fact that the efficiency of the steam-raising plant is lower in the case of small installations. Current prices for coal and coke have been taken at Rs. 10 and Rs. 30 per ton respectively, delivered into railway wagons at the sources of supply.

Transport charges.

110. In estimating the cost of raw materials at the factories and finished product at the depots, we have based our calculations of freight charges on rates furnished to us by the Railway Department (Railway Board). We also examined the question of utilising coastal and river transport for the conveyance of the raw materials and finished product but found that, under the present abnormal conditons, the cost of transport by sea or river compares unfavourably with rail transport. When however conditions become normal the possibility of making use of such alternative means of transport should not be overlooked.

Economies resulting from use of anhydrite.

111. It has been mentioned in paragraph 30 that anhydrite is a better raw material than gypsum on account of the lower consumption due to the absence of the water content of the latter. There are, however, other economies in the process itself arising from the use of anhydrite in place of gypsum, since the combined water content of gypsum represents in effect an impurity which has to be removed, resulting in an increased consumption of steam in the process. The decreased usage of steam in the anhydrite process will, however, be partly offset in a factory generating its own power by the reduction in the electric power which can be generated from the process steam and the consequent necessity of purchasing additional power from an external source of supply. We estimate that if the cost of winning anhydrite is assumed to be the same per ton as that of gypsum, then the use of anhydrite will result in a reduction of the cost of sulphate of ammonia by about Rs. 3.5 per ton, assuming both minerals to be obtained from Khewra and utilised at Harduaganj. The advantages of anhydrite are therefore clear, but it is not possible to assume that this material will be available in the quantity required until the results of the survey mentioned in paragraph 30 are known and it has therefore been necessary to base our estimates of the cost of production of sulphate of ammonia on the assumption that gypsum is used as the raw material. If however the survey should establish the existence of sufficient reserves of anhydrite, the factory would obviously take advantage of the more economic material.

Sources of supply of gypsum and anhydrite.

112. As mentioned in paragraph 34, Trichinopoly gypsum would be the most economic source of supply for a factory in South India, factories in other parts of the country drawing their supplies either from the Salt Range or from Rajputana. The estimates of production costs for the various schemes of manufacture of 350,000 tons per annum of sulphate of ammonia described in paragraphs 82—85 are given in Annexure C, and in each case the cost of the gypsum delivered to the factory is given. The estimates for factories at Bezwada and Trichinopoly assume that Trichinopoly gypsum is used, and the Bombay factory estimate is based upon the use of Jamsar gypsum; all other factories for which estimates have been prepared are assumed to be supplied with gypsum from Khewra. In considering the sources of supply of calcium sulphate, either in the form of anyhdrite or gypsum, for the recommended scheme involving the establishment of a factory at Harduaganj, it is necessary to examine the question in somewhat greater detail, since

plans for the development of the appropriate quarries or mines will have to be made at an early date.

113. It will be clear from paragraph 111 that if anhydrite can be obtained in the required amount from Khewra and if the cost of winning does not differ appreciably from that of gypsum, then it will be more economic to use anhydrite than to use gypsum from the Salt Range or from Rajputana (gypsum from both these sources will cost approximately the same per ton of calcium sulphate delivered at Harduaganj). We therefore recommend that anhydrite from Khewra should be used, if proved to be available in the quantities required, as the sole source of calcium sulphate for the Harduaganj factory. If it should be found that anhydrite is not available in the quantity required, then we recommend that the bulk of the gypsum be obtained from Khewra, which has the advantage over other sources of possessing a strong Government mining organisation already in existence. We also recommend, however, that careful consideration be given to the development of a second source of supply at Jamsar in Bikaner State for, say, not more than a quarter of the total requirements, with the object of decreasing the risk of interruption of supply by transport or other difficulties. The provision of this safeguard would involve the expenditure, on the part of any organisation working the Jamsar deposits, of about Rs. 12 lakhs additional capital, and would add to the cost of production of sulphate of ammonia an amount estimated to be not more than one rupee per ton.

Cost of gypsum.

114. In preparing the estimate of the cost of production at the recommended factory at Harduaganj, we have assumed that the requirements of calcium sulphate are obtained as gypsum from Khewra since the substitution of a proportion of Jamsar gypsum, if considered advisable, will affect the cost of production only to the minor extent mentioned above. A reference to Appendix 3 will show that the estimated cost of gypsum or anhydrite at the different sources of supply varies from Rs. 2.31 to Rs. 4.07 per ton, but after careful consideration we have reached the conclusion that it will be reasonable for the purpose of our estimates to assume that the cost will be approximately that given for anhydrite from Khewra deposits, *viz.*, Rs. 4 per ton. Our reasons for this decision are that these deposits are the property of the Government, that they are at present being worked under a well established system of governmental control and management and that sales are already being made to industrial concerns at a somewhat lower price than the figure we have taken. Although the estimates indicate that the cost of winning gypsum at other localities may be less than the figure chosen, we consider that since the mining rights of these areas have been leased to private concerns, the costs given in Appendix 3 may not be achieved, due to a number of factors which are not applicable to a Government organisation. Among these factors are such items as the amount of capital which the lessees would be prepared to spend and the return on capital they would require, both of which would be influenced by the length of any contract negotiated. Since a large proportion of the cost of gypsum delivered to the factory consists of freight charges, it will be obvious that this cost will not be greatly affected by our assumption of a uniform price at source. We consider therefore that the rate we have assumed is a safe figure for the purpose of our estimates.

115. As mentioned in paragraph 35, the great distance of a factory in South India from the Punjab and Rajputana necessitates the utilisation of

gypsum from Trichinopoly for factories located in this part of the country, despite the less favourable material from this source. We have obtained, from the Company which holds concessions for the exploitation of these deposits, estimates of the cost of production of gypsum ; these amount to an average of Rs. 20 per ton on rail without management and supervision charges. In consultation with officials of the Madras Government, however, we have decided to base the cost of sulphate of ammonia produced in Southern India on a price for gypsum of Rs. 15 per ton on rail, since it is considered that a reduction in cost could be achieved by the utilisation of more modern methods of transport between quarry and railway.

Other materials for process and repairs

116. The other materials required for process and repair purposes will include :—

(*a*) Various items such as catalysts, iron oxide for sulphur removal, chemicals for the removal of carbon dioxide and monoxide and for water softening, lubricants and such minor items as cleaning and other material necessary for the running of a chemical plant.

(*b*) Various materials and spares needed for the repair of the plant and machinery installed and for its maintenance in the state of efficiency demanded by the nature of the process.

(*c*) Sundry other items necessary for the running of a large factory, including a number of incidental expenses which are not, strictly speaking, " materials ".

It has been assumed that the majority of these special materials will require to be imported from abroad and a suitable allowance has been made in the cost for this purpose. There appears, however, to be no reason why the manufacture of many of these materials, for example the catalysts, should not ultimately be undertaken in this country.

Labour and supervision.

117. The staff and labour requirements are discussed in detail in paragraphs 62—76 and the figures given therein have been taken as the basis for our estimate of the cost of this item.

Purchased electric power.

118. In estimating the cost of electric power to be purchased from outside sources of supply we have assumed a rate of 0.4 annas per kilowatt hour. For factories of 50,000 tons per annum all power will be purchased and the power consumption per ton of sulphate will be 570 kilowatt hours. For the larger factories about 90% of the electric power will be generated in the power station within the factory and only about 57 kilowatt hours per ton of sulphate will be purchased from outside sources of power supply.

Water supply.

119. It has been pointed out in paragraph 52 that the quantity of water required for a sulphate of ammonia factory depends to a considerable extent on the precise design of the manufacturing plants. For the purposes of our estimate we have assumed a figure of 5,000 gallons per ton of sulphate, to which has been added the amount necessary for the housing estate, estimated at 40 gallons per head per day. No separate item for water appears in the cost statement, since power, labour, repair and capital charges for the water supply installation are included under their appropriate headings for the factory as a whole.

120. In our estimate of the cost of bags for packing, we have assumed that three-quarters of the output will be packed in 2 cwt. bags and the remaining quarter in 80 lbs. bags. In the interest of economy it would be preferable to adopt the 2 cwt. bag as the standard but, as it is unlikely that this will meet the requirements of all cultivators, we have adopted the compromise indicated.

Cost of materials for packing.

121. In the estimates of cost of production, provision has been made for interest charges at 4% on the total estimated capital expenditure, this provision having been made with the approval of the Government of India. We have included in our estimate of cost of production a provision for depreciation calculated at $2\frac{1}{2}\%$ on buildings and foundations and $7\frac{1}{2}\%$ on plant and equipment in the factory. These rates are, in our opinion, adequate and will accumulate a fund which will amply cover the cost of replacements of assets when such replacements become necessary. No provision has been made for depreciation of the stocks of raw materials and starting expenses, since variation in stocks can appropriately be charged to operating expenses. The overhead charges on the capital expenditure connected with the construction of quarters and amenities for the staff and labour include provision for interest, depreciation and maintenance at 4%, $1\frac{1}{2}$% and 1% per annum respectively on the prime cost incurred on the housing scheme. Since we assume that rents will be paid by all staff occupying the houses, we have estimated a recovery on this account of 10% of the total salary bill of the factory.

Overhead charges, interest and depreciation.

122. In Annexure C details are given of the production cost for factories of various sizes and for different combinations of factories making up the total production of 350,000 tons per annum.

SUMMARY AND CONCLUSIONS

123. The conclusions reached and the recommendations made in the foregoing pages may be summarised as follows :—

(*i*) We have investigated the technical problems involved in the manufacture of sulphate of ammonia in British India in quantities up to 350,000 tons per annum.

(*ii*) Having regard to the raw materials and power available in India, we are of opinion that the most economic method of manufacture is that employing water-gas made from coke to produce the necessary ammonia, followed by conversion to sulphate by the gypsum or anhydrite process. We recommend that coke should be obtained from the Bihar-Bengal coalfields and gypsum or anhydrite from Khewra in the Punjab.

(*iii*) We have considered in detail several schemes of production involving various numbers of factories in different parts of India, and have reached the conclusion that the most economic scheme is that in which the whole production is carried out in a single factory. We estimate that the approximate capital cost of such a factory will be Rs. 10.1 crores, and that the approximate cost of the finished product will be Rs. 114 per ton at the factory.

(*iv*) Taking into account the raw materials available and the most economic distribution of the finished product together with all other relevant factors, such as water supply, power supply, transport, etc., we are of opinion that the best site for such a factory is in the Gangetic Plain. Of the various possible sites in this area, we recommend Harduaganj in the United Provinces.

(*v*) We have estimated the amount and approximate value of plant which it will be necessary to import from outside India, making the fullest possible use of materials and labour available in India, and have reached the conclusion that facilities exist sufficient to enable about Rs. 6 crores to be spent in this country out of the total of Rs. 10.1 crores. Since, however, in some cases such facilities are of limited capacity, it may be necessary in the interest of rapid completion of the project to import from outside India a somewhat greater proportion than is indicated by the above figures.

(*vi*) We have considered whether nitrogenous fertiliser in a form other than sulphate of ammonia can be more satisfactorily manufactured under Indian conditions generally or locally, but have reached the conclusions that no fertiliser other than sulphate of ammonia should be considered for the present purpose.

(*vii*) It has therefore been unnecessary to estimate the capital and operating cost of manufacture of such alternative nitrogenous fertiliser.

(*viii*) In addition to the above conclusions and recommendations, which are specifically required by our terms of reference, we recommend :—

(*a*) that work should be instituted to determine the suitability of ammonium nitrate as a fertiliser for Indian conditions, in order to take advantage for future nitrogenous fertiliser requirements of a material which should be cheaper to produce (paragraph 12).

(*b*) that in the event of extensions to the present scheme of production being contemplated, the possibility of utilising lower grade non-coking coal for gas production be investigated (paragraph 20).

(*c*) that a survey should be undertaken to investigate the quantity of anhydrite in the Salt Range in order that this raw material can be used in preference to gypsum, thereby effecting certain economies in the manufacture of sulphate of ammonia. Funds have already been allocated by the Government for this purpose, and it is hoped that the results will be available before detailed design of the plant is undertaken (paragraphs 30 and 111).

(*d*) that consideration should be given, in the event of anhydrite not being available, to the desirability of developing the production of gypsum in Rajputana in order to utilise a second source of supply (paragraph 113).

(*e*) that a scheme be instituted for training the technical staff necessary for running the factory. This will involve sending selected candidates overseas to obtain experience in fertiliser factories of the type proposed for India (paragraph 68).

We have the honour to be,

Sir,

Your most obedient servants,

G. S. GOWING (*Leader*).

J. RIGG.

T. H. RILEY.

ANNEXURE A.

Proceedings of the Mission.

On the conclusion of the meetings with the Consultative Committee in New Delhi, the Mission accompanied by Sir James Pitkeathly and Mr. C. C. M. Broghton proceeded on tour on the 24th June 1944, and visited various places in the Provinces and States. A list of the places visited and dates of the visits is given in Statement I. The Officers of the Provincial Governments and States, who had been nominated by their respective Governments to assist the Mission in their investigations and to prepare information and suggestions for their consideration, arranged meetings with the representatives of Government Departments, Commercial Bodies and other interested parties. Conferences attended by all officials of the Provinces and States interested in the Mission's investigations were held at Patna, Dhanbad, Calcutta, Cuttack, Madras, Bangalore, Hyderabad, Poona, Bombay, Nagpur, Lucknow, Cawnpore, Bikaner and Lahore, and at these meetings the Mission were afforded full opportunities for detailed discussion of the information which had been prepared for their use. In Statement II, a list is given of these officials and others whom the Mission were privileged to meet.

2. During their visits to Calcutta, Bombay, and Cawnpore, the Mission, by invitation, attended special meetings of the Indian Chemical Manufacturers' Association, the All India Manufacturers' Association and the Merchants Chamber of the United Provinces respectively. Representatives of the South India Chamber of Commerce, the Andhra Chamber of Commerce and the Muslim Chamber of Commerce were invited by the Government of Madras to meet the Mission at a Conference held in Madras. At Dhanbad, a deputation of colliery owners and coke producers met the Mission and interesting information in regard to coal and coke supplies was given by the deputation ; visits were then paid, in the company of Mr. S. M. Dhar, I.C.S. Development Commissioner, Government of Bihar, and Dr. H. K. Sen, Director of Industries, Government of Bihar, to some of the larger coke ovens in the Jharia coalfield.

3. In order to obtain first hand knowledge of the capacity of the engineering industry with a view to utilising any available and suitable capacity for the manufacture in India of the greatest possible portion of the plant and equipment required for the project, the Mission visited the engineering and other firms shown in Statement III and by the courtesy of the Additional Director General, Ordnance Factories, the Mission were able to inspect a number of Ordnance Factories engaged on munitions production. The visits to many of these establishments also enabled the Mission to obtain valuable information on the general organisation of large scale factories, of the type most closely related to the projected fertiliser factory, under the conditions ruling in India. In addition the Mission interviewed representatives of a number of firms other than those engaged in engineering work, in order to obtain from them information required in connection with their investigations. A list of the firms whose representatives were interviewed is given in Statement IV.

4. By the courtesy of the Mysore Government the Mission, accompanied by Mr. E. V. Ganapati Iyer and Mr. B. Vishvanath, inspected Sulphate of Ammonia Factory at Belagula. In Bangalore a visit was paid to the Indian Institute of Science, where they were received by the Director, Sir Jnan Chandra Ghosh, who conducted them through the various Departments of the

Institute. In Hyderabad the Mission visited the Osmania University and were received and conducted round the different Departments by Nawab Zain Yar Jung Bahadur who, with Dr. Qureshi, Professor of Technological Chemistry, gave a most interesting account of the design, organisation and activities of the University.

5. From Bangalore, the Mission visited Trichinopoly by air on the 23rd July 1944, and from there proceeded by road to inspect the gypsum deposits which are being worked in the Uttattur area. Dr. Krishnan of the Geological Survey of India was present during the inspection and Mr. Seshasayee, representing the concessionaires, met the Mission at Trichinopoly.

6 On the 29th July 1944 visits were paid to the Meteorological Office at Poona and the Indian Waterways Experiment Station, Lake Fife, Khadakwasla (near Poona).

7. On the 18th and 19th August 1944, the Mission accompanied by Dr. H. Crookshank, Offg. Director, Geological Survey of India, Mr. E. B. Lewis, Chief Mining Engineer, Salt Range, Central Excise, Mr. B. A. Kureshi, I.C.S., Under Secretary, Electricity and Industries Department and Dr. J. L. Sarin, Industrial Chemist, Government of the Punjab, inspected the gypsum deposits at Khewra and Daud-Khel in the Salt Range. On the 25th August 1944 the Mission visited Bikaner State, accompanied by Mr. E. B. Lewis. They were met by the Home & Development Minister and Mining Engineer of the State and together inspected the gypsum deposits at Jamsar. On the 26th August 1944 the deposits at Pilanwasi, Badwasi and Dakoria in Jodhpur State were inspected.

8. Possible sites for the construction of factories for the production of sulphate of ammonia were examined at the following places on the dates mentioned.

Place.		*Date of Inspection.*
Sindri near Dhanbad	(Bihar)	29th June 1944.
Cuttack	(Orissa)	10th July 1944.
Kalyan	(Bombay)	2nd Aug. 1944.
Jubbulpore	(Central Provinces)	7th Aug. 1944.
Harduaganj	(United Provinces)	13th Aug. 1944.
Mari Indus	(Punjab)	20th Aug. 1944.
Amritsar	(Punjab)	21st Aug. 1944.

The Mission were accompanied during visits to the above sites by the officials of the respective Provincial Governments.

9. At the invitation of His Highness The Maharaja of Patiala, the Mission visited Dochi on the 27th September 1944, for a discussion with His Highness and officials of the State on the possibility of establishing a factory for the production of sulphate of ammonia in Patiala.

ANNEXURE B—PART I.

APPROXIMATE CAPITAL COSTS OF FACTORIES FOR THE PRODUCTION OF SULPHATE OF AMMONIA

Scheme for six factories.

(*i*) APPROXIMATE CAPITAL COST OF A FACTORY FOR THE PRODUCTION OF 100,000 TONS PER ANNUM OF SULPHATE OF AMMONIA AT SINDRI NEAR DHANBAD.

	Rs.
1. *Production plants*—	
(*a*) Ammonia plant	1,33,00,000
(*b*) Sulphate plant	88,00,000
(*c*) Product storage and packing	22,00,000
2. *Service plants and equipment*—	
(*a*) Boiler	65,00,000
(*b*) Water supply and cooling water systems ..	46,00,000
(*c*) Sundry services	52,00,000
(*d*) Laboratories, workshops, stores, etc. ..	11,00,000
(*e*) Railways and roads	12,20,000
(*f*) Land purchase, surveys and drainage ..	2,80,000
3. *Stocks of materials and starting expenses* ..	18,00,000
4. *Housing estate including land purchase and hospital*	39,00,000
Total ..	4,89,00,000

(*ii*—*vi*) APPROXIMATE CAPITAL COST OF A FACTORY FOR THE PRODUCTION OF 50,000 TONS PER ANNUM OF SULPHATE OF AMMONIA

	Rs.
1. *Production plants*—	
(*a*) Ammonia plant	90,50,000
(*b*) Sulphate plant	77,50,000
(*c*) Product storage and packing	15,50,000
2. *Service plants and equipment*—	
(*a*) Boiler plant	18,00,000
(*b*) Water supply and cooling water systems ..	30,00.000
(*c*) Sundry services	40,00,000
(*d*) Laboratories, workshops, stores, etc. ..	6,50,000
(*e*) Railways and roads	4,00,000
(*f*) Land purchase, surveys and drainage ..	1,50,000
3. *Stocks of materials and starting expenses* ..	10,00,000
4. *Housing estate including land purchase and hospital*	28,50,000
Total ..	3,22,00,000

Scheme for three factories.

(*i*) APPROXIMATE CAPITAL COST OF A FACTORY FOR THE PRODUCTION OF 116,700 TONS PER ANNUM OF SULPHATE OF AMMONIA AT HARDUAGANJ.

	Rs.
1. *Production plants*—	
(*a*) Ammonia plant	1,46,00,000
(*b*) Sulphate plant	91,70,000
(*c*) Product storage and packing	24,80,000
2. *Service plants and equipment*—	
(*a*) Boiler and power plants	84,00,000
(*b*) Water supply and cooling water systems ..	26,00,000
(*c*) Sundry services	53,00,000
(*d*) Laboratories, workshops, stores, etc. ..	10,50,000
(*e*) Railways and roads	6,50,000
(*f*) Land purchase, surveys and drainage ..	3,00,000
3. *Stocks of materials and starting expenses* ..	20,00,000
4. *Housing estate including land purchase and hospital*	41,50,000
Total ..	5,07,00,000

(ii) APPROXIMATE CAPITAL COST OF A FACTORY FOR THE PRODUCTION OF 116,700 TONS PER ANNUM OF SULPHATE OF AMMONIA AT SINDRI NEAR DHANBAD.

	Rs.
1. *Production plants*—	
(*a*) Ammonia plant	1,46,00,000
(*b*) Sulphate plant	91,70,000
(*c*) Product storage and packing	24,80,000
2. *Service plants and equipment*—	
(*a*) Boiler and power plants	84,00,000
(*b*) Water supply and cooling water systems ..	50,00,000
(*c*) Sundry services	53,00,000
(*d*) Laboratories, workshops, stores, etc. ..	11,50,000
(*e*) Railways and roads	12,50,000
(*f*) Land purchase, surveys and drainage ..	3,00,000
8. *Stocks of materials and starting expenses* ..	20,00,000
4. *Housing estate including land purchase and hospital*	41,50,000
Total ..	5,38,00,000

Scheme for three factories—contd.

(iii) APPROXIMATE CAPITAL COST OF A FACTORY FOR THE PRODUCTION OF 116,700 TONS PER ANNUM OF SULPHATE OF AMMONIA AT TRICHINOPOLY.

	Rs.
1. *Production plants*—	
(*a*) Ammonia plant	1,46,00,000
(*b*) Sulphate plant	91,70,000
(*c*) Product storage and packing	24,80,000
2. *Service plants and equipment*—	
(*a*) Boiler and power plants	84,00,000
(*b*) Water supply and cooling water systems ..	42,00,000
(*c*) Sundry services	53,00,000
(*d*) Laboratories, workshops, stores, etc. ..	10,50,000
(*e*) Railways and roads	6,50,000
(*f*) Land purchase, surveys and drainage ..	3,00,000
3. *Stocks of materials and starting expenses* ..	20,00,000
4. *Housing estate including land purchase and hospital*	41,50,000
Total ..	5,23,00,000

Scheme for two factories

(*i*) APPROXIMATE CAPITAL COST OF A FACTORY FOR THE PRODUCTION OF 250,000 TONS PER ANNUM OF SULPHATE OF AMMONIA AT HARDUAGANJ

	Rs.
1. *Production plants*—	
(*a*) Ammonia plant	2,14,00,000
(*b*) Sulphate plant	1,50,00,000
(*c*) Product storage and packing	39,00,000
2. *Service plants and equipment*—	
(*a*) Boiler and power plants	1,54,00,000
(*b*) Water supply and cooling water systems ..	36,00,000
(*c*) Sundry services	76,00,000
(*d*) Laboratories, workshops, stores, etc. ..	15,00,000
(*e*) Railways and roads	11,00,000
(*f*) Land purchase, surveys and drainage ..	4,50,000
3. *Stocks of materials and starting expenses* ..	40,00,000
4. *Housing estate including land purchase and hospital* ..	58,50,000
Total ..	7,98,00,000

(*ii*) APPROXIMATE CAPITAL COST OF A FACTORY FOR THE PRODUCTION OF 100,000 TONS PER ANNUM OF SULPHATE OF AMMONIA AT TRICHINOPOLY

	Rs.
1. *Production plants*—	
(*a*) Ammonia plant	1,33,00,000
(*b*) Sulphate plant	88,00.000
(*c*) Product storage and packing	22.00,000
2. *Service plants and equipment*—	
(*a*) Boiler and power plants	65,00,000
(*b*) Water supply and cooling water systems ..	38,00,000
(*c*) Sundry services	52,00,000
(*d*) Laboratories, workshops, stores, etc. ..	10,00,000
(*e*) Railways and roads	6,20,000
(*f*) Land purchase, surveys and drainage ..	2,80,000
3. *Stocks of materials and starting expenses* ..	18,00,000
4. *Housing estate including land purchase and hospital* ..	39,00,000
Total ..	**4,74,00,000**

Scheme for one factory

APPROXIMATE CAPITAL COST OF A FACTORY FOR THE PRODUCTION OF 350,000 TONS PER ANNUM OF SULPHATE OF AMMONIA AT (*a*) HARDUAGANJ

	Rs.
1. *Production plants*—	
(*a*) Ammonia plant	2,62,50,000
(*b*) Sulphate plant	2,10,50,000
(*c*) Product storage and packing	50,50,000
2. *Service plants and equipment*—	
(*a*) Boiler and power plants	1,98,50,000
(*b*) Water supply and cooling water systems ..	45,00,000
(*c*) Sundry services	92,50,000
(*d*) Laboratories, workshops, stores, etc. ..	15,00,000
(*e*) Railways and roads	14,00,000
(*f*) Land purchase, surveys and drainage ..	6,00,000
3. *Stocks of materials and starting expenses* ..	50,00,000
4. *Housing estate including land purchase and hospital*	67,50,000
Total ..	10,12,00,000

APPROXIMATE CAPITAL COST OF A FACTORY FOR THE PRODUCTION OF 350,000 TONS PER ANNUM OF SULPHATE OF AMMONIA AT (*b*) SINDRI NEAR DHANBAD

	Rs.
1. *Production plants*—	
(*a*) Ammonia plant	2,62,50,000
(*b*) Sulphate plant	2,10,50,000
(*c*) Product storage and packing	50,50,000
2. *Service plants and equipment*—	
(*a*) Boiler and power plants	1,98,50,000
(*b*) Water supply and cooling water systems ..	80,00,000
(*c*) Sundry services	92,50,000
(*d*) Laboratories, workshops, stores, etc. ..	15,00,000
(*e*) Railways and roads	20,00,000
(*f*) Land purchase, surveys and drainage ..	6,00,000
3. *Stocks of materials and starting expenses* ..	50,00,000
4. *Housing estate including land purchase and hospital*	67,50,000
Total ..	10,53,00,000

APPROXIMATE CAPITAL COSTS FOR VARIOUS SCHEMES OF PRODUCTION OF 350,000 TONS PER ANNUM OF SULPHATE OF AMMONIA

Site.	*Output tons per annum.*	*Approximate Capital Cost.*
Scheme for six factories—		
		Rs.
(*i*) Sindri (Dhanbad)	100,000	4,89,00,000
(*ii*) Amritsar	50,000	3,22,00,000
(*iii*) Moghal Sarai	50,000	3,22,00,000
(*iv*) Bombay	50,000	3,22,00,000
(*v*) Bezwada	50,000	3,22,00,000
(*vi*) Trichinopoly	50,000	3,22,00.000
Total for scheme ..	350,000	20,99,00,000
Scheme for three factories—		
(*i*) Harduaganj	116,700	5,07,00.000
(*ii*) Sindri (Dhanbad)	116,700	5,38,00.000
(*iii*) Trichinopoly	116,700	5,23,00,000
Total for scheme ..	350,000	15,68,00.000
Scheme for two factories		
(*i*) Harduaganj	250,000	7,98,00.000
(*ii*) Trichinopoly	100,000	4,74,00.000
Total for scheme ..	350,000	12,72,00,000
Scheme for single factory—		
(*a*) Harduaganj	350,000	10,12,00,000
(*b*) Sindri	350,000	10,53,00,000

ANNEXURE B—PART II

ALLOCATION OF THE ESTIMATED CAPITAL EXPENDITURE OF RECOMMENDED FACTORY BETWEEN INDIA AND ABROAD

Estimated expenditure in India—	Rs.
Plant and equipment obtained in India	1,32,00,000
Factory buildings and structures obtained in India ..	57,00,000
Land purchase (factory only) and surveys	2,00,000
Civil work and foundations	98,00,000
Railways and roads	14,00,000
Laboratories, workshops, stores, offices, canteens, first-aid, **fire and safety services**	12,50,000
Customs and rail charges	80,00,000
Construction, tools and plant	16,00,000
Erection : Factory buildings and all plant and equipment ..	71,00,000
Stocks of materials and starting expenses	50,00,000
Housing estate	67,50,000
Total ..	6,00,00,000
Estimated expenditure abroad—	
Plant, equipment and engineering services including ocean freight	4,12,00,000
GRAND TOTAL ..	10,12,00,000

ANNEXURE C

APPROXIMATE COST OF PRODUCTION OF SULPHATE OF AMMONIA

Scheme for six factories

(i) APPROXIMATE COST OF PRODUCTION OF 100,000 TONS PER ANNUM OF SULPHATE OF AMMONIA AT SINDRI (NEAR DHANBAD).

	Rs. per annum.	Rs. per ton.
Raw materials—		
Coal 71,000 tons at Rs. 12·5 per ton ..	8,90,000	8·9
Coke 51,000 tons at Rs. 32·6 per ton ..	16,60,000	16·6
Gypsum 153,000 tons at Rs. 23·6 per ton ..	36,10,000	36·1
Other materials	12,20,000	12·2
Labour and supervision	11,60,000	11·6
Purchased electric power	1,40,000	1·4
Packing materials	8,50,000	8·5
Works cost ..	95,30,000	95·3
Overhead charges—		
Interest (Factory)	18,00,000	18·0
Depreciation (Factory)	26,60 000	26·6
Housing estate overheads	2,10,000	2·1
Total cost f.o.r. factory ..	1,42,00,000	142·0

(ii) APPROXIMATE COST OF PRODUCTION OF 50,000 TONS PER ANNUM OF SULPHATE OF AMMONIA AT AMRITSAR.

	Rs. per annum.	Rs. per ton.
Raw materials—		
Coal 33,000 tons at Rs. 23·9 per ton ..	7,90,000	15·8
Coke 25,500 tons at Rs. 44·0 per ton ..	11,20,000	22·4
Gypsum 76.500 tons at Rs. 8·1 per ton ..	6,20,000	12·4
Other materials	6,10,000	12·2
Labour and supervision	8,10,000	16·2
Purchased electric power	7,15,000	14·3
Packing materials	4,25,000	8·5
Works cost ..	50,90,000	101·8
Overhead charges—		
Interest (Factory)	11,75,000	23·5
Depreciation (Factory)	17,80,000	35·6
Housing estate overheads	1,50,000	3·0
Total cost f.o.r. factory ..	81,95,000	163·9

Scheme for six factories—(contd.)

(*iii*) APPROXIMATE COST OF PRODUCTION OF 50,000 TONS PER ANNUM OF SULPHATE OF AMMONIA AT MOGHAL SARAI.

	Rs. per annum.	Rs. per ton.
Raw materials—		
Coal 33,000 tons at Rs. 18·7 per ton ..	6,15,000	12·3
Coke 25,500 tons at Rs. 38·7 per ton ..	9,85,000	19·7
Gypsum 76,500 tons at Rs. 19·6 per ton ..	15,00,000	30·0
Other materials	6,10,000	12·2
Labour and supervision	8,10.000	16·2
Purchased electric power	7,15,000	14·3
Packing materials	4,25,000	8·5
Works cost ..	56,60,000	113·2
Overhead charges—		
Interest (Factory)	11,75,000	23·5
Depreciation (Factory)	17,80,000	35·6
Housing estate overheads	1 50,000	3·0
Total cost f.o.r. factory ..	87,65,000	175·3

(*iv*) APPROXIMATE COST OF PRODUCTION OF 50,000 TONS PER ANNUM OF SULPHATE OF AMMONIA AT BOMBAY.

	Rs. per annum.	Rs. per ton.
Raw materials—		
Coal 33,000 tons at Rs. 21·3 per ton ..	7,05.000	14·1
Coke 25,500 tons at Rs. 46·3 per ton ..	11,80,000	23·6
Gypsum 78,500 tons at Rs. 17·4 per ton ..	13 65,000	27·3
Other materials	6,10,000	12·2
Labour and supervision	8,10,000	16·2
Purchased electric power	7,15,000	14·3
Packing materials	4,25,000	8·5
Works cost ..	58,10,000	116·2
Overhead charges—		
Interest (Factory)	11,75,000	23·5
Depreciation (Factory)	17,80,000	35·6
Housing estate overheads	1,50,000	3·0
Total cost f.o.r. factory ..	89,15 000	178·3

Scheme for six factories—(contd.)

(v) Approximate cost of production of 50,000 tons per annum of sulphate of ammonia at Bezwada

		Rs. per annum.	Rs. per ton.
Raw materials			
Coal 33,000 tons at Rs. 13·35 per ton	..	4,40,000	8·8
Coke 25,500 tons at Rs. 43·1 per ton	..	11,00,000	22·0
Gypsum 78,500 tons at Rs. 25·1 per ton	..	19,70,000	39·4
Other materials	..	6,10,000	12·2
Labour and supervision	..	8,10,000	16·2
Purchased electric power	..	7,15,000	14·3
Packing materials	..	4,25,000	8·5
Works cost	..	60,70,000	121·4
Overhead charges.			
Interest (Factory)	..	11,75,000	23·5
Depreciation (Factory) ..	..	17,80,000	35·6
Housing estate overheads ..	..	1,50,000	3·0
Total cost f.o.r. factory	..	91,75,000	183·5

(vi) Approximate cost of production of 50,000 tons per annum of sulphate of ammonia at Trichinopoly.

		Rs. per annum.	Rs. per ton.
Raw materials.			
Coal 33,000 tons at Rs. 24·2 per ton	..	8,00,000	16·0
Coke 25,500 tons at Rs. 52·3 per ton	..	13,35,000	26·7
Gypsum 78,500 tons at Rs. 17·7 per ton	..	13,90,000	27·8
Other materials	..	6,10,000	12·2
Labour and supervision	..	8,10,000	16·2
Purchased electric power	..	7,15,000	14·3
Packing materials	..	4 25,000	8·5
Works cost	..	60,85,000	121·7
Overhead charges.			
Interest (Factory)	..	11,75,000	23·5
Depreciation (Factory) ..	..	17,80,000	35·6
Housing estate overheads ..	..	1 50,000	3·0
Total cost f.o.r. factory	..	91,90,000	183·8

Scheme for three factories

(i) APPROXIMATE COST OF PRODUCTION OF 116,700 TONS PER ANNUM OF SULPHATE OF AMMONIA AT HARDUAGANJ.

	Rs. per annum.	Rs. per ton.
Raw materials		
Coal 82,800 tons at Rs. 21·2 per ton ..	17,50,000	15·0
Coke 59,500 tons at Rs. 41·3 per ton ..	24,60,000	21·1
Gypsum 179,000 tons at Rs. 13·7 per ton ..	24,50,000	21·0
Other materials	14,20,000	12·2
Labour and supervision	12,30,000	10·5
Purchased electric power	1,60,000	1·4
Packing materials	9,90,000	8·5
Works cost ..	1 04,60,000	89·7
Overhead charges.		
Interest (Factory)	18,60,000	15·9
Depreciation (Factory)	28,40,000	24·3
Housing estate overheads	2,30,000	2·0
Total cost f.o.r. factory ..	1,53,90,000	131·9

(ii) APPROXIMATE COST OF PRODUCTION OF 116,700 TONS PER ANNUM OF SULPHATE OF AMMONIA AT SINDRI (NEAR DHANBAD).

	Rs. per annum.	Rs. per ton.
Raw materials		
Coal 82,800 tons at Rs. 12·5 per ton ..	10,35,000	8·9
Coke 59,500 tons at Rs. 32·6 per ton ..	19,40,000	16·6
Gypsum 179,000 tons at Rs. 23·6 per ton ..	42,20,000	36·1
Other materials	14,20,000	12·2
Labour and supervision	12,30,000	10·5
Purchased electric power	1,60,000	1·4
Packing materials	9,90,000	8·5
Works cost ..	1,09,95,000	94·2
Overhead charges.		
Interest (Factory)	19,80,000	17·0
Depreciation (Factory)	29,20,000	25·0
Housing estate overheads	2,30,000	2·0
Total cost f.o.r. factory ..	**1,61,25,000**	**138·2**

Scheme for three factories—(contd.)

(ii) APPROXIMATE COST OF PRODUCTION OF 116,700 TONS PER ANNUM OF SULPHATE OF AMMONIA AT TRICHINOPOLY.

	Rs. per annum.	Rs. per ton.
Raw materials		
Coal 82,800 tons at Rs. 24·2 per ton ..	20,05,000	17·2
Coke 59,500 tons at Rs. 52·3 per ton ..	31,10,000	26·6
Gypsum 183,000 tons at Rs. 17·7 per ton ..	32,40,000	27·8
Other materials	14,20,000	12·2
Labour and supervision	12 30,000	10·5
Purchased electric power	1,60,000	1·4
Packing materials	9,90,000	8·5
Works cost ..	1,21,55,000	104·2
Overhead charges.		
Interest (Factory)	19,20,000	16·5
Depreciation (Factory)	28,80,000	24·7
Housing estate overheads	2,30,000	2·0
Total cost f.o.r. factory ..	1,71,85,000	147·4

Scheme for two factories

(*i*) APPROXIMATE COST OF PRODUCTION OF 250,000 TONS PER ANNUM OF SULPHATE OF AMMONIA AT HARDUAGANJ.

	Rs. per annum.	Rs. per ton.
Raw materials		
Coal 177,000 tons at Rs. 21·2 per ton ..	37,50,000	15·0
Coke 128,000 tons at Rs. 41·3 per ton ..	52,90,000	21·2
Gypsum 382,000 tons at Rs. 13·7 per ton ..	52,30,000	20·9
Other materials	30,50,000	12·2
Labour and supervision	18,30,000	7·3
Purchased electric power	3,50,000	1·4
Packing materials	21,20,000	8·5
Works cost ..	**2,16,20,000**	**86·5**
Overhead charges.		
Interest (Factory)	29,60,000	11·8
Depreciation (Factory)	44,50,000	17·8
Housing estate overheads	3,25,000	1·3
Total cost f.o.r. factory ..	2,93,55,000	117·4

(*ii*) APPROXIMATE COST OF PRODUCTION OF 100,000 TONS PER ANNUM OF SULPHATE OF AMMONIA AT TRICHINOPOLY.

	Rs. per annum.	Rs. per ton.
Raw materials		
Coal 71,000 tons at Rs. 24·2 per ton ..	17,20,000	17·2
Coke 51,000 tons at Rs. 52·3 per ton ..	26,70,000	26·7
Gypsum 157,000 tons at Rs. 17·7 per ton ..	27,80,000	27·8
Other materials	12,20,000	12·2
Labour and supervision	11,60,000	11·6
Purchased electric power	1,40,000	1·4
Packing materials	8,50,000	8·5
Works cost ..	1,05,40,000	105·4
Overhead charges.		
Interest (Factory)	17,40,000	17·4
Depreciation (Factory)	26,30,000	26·3
Housing estate overheads	2,10,000	2·1
Total cost f.o.r. factory ..	1,51,20,000	**151·2**

Scheme for single factory

(a) APPROXIMATE COST OF PRODUCTION OF 350,000 TONS PER ANNUM OF SULPHATE OF AMMONIA AT HARDUAGANJ.

		Rs. per annum.	Rs. per ton.
Raw materials			
Coal 249,000 tons at Rs. 21·2 per ton	..	52,80,000	15·1
Coke 178,000 tons at Rs. 41·3 per ton	..	73,50 000	21·0
Gypsum 536,000 tons at Rs. 13·7 per ton	..	73,40,000	21·0
Other materials	..	42,70 000	12·2
Labour and supervision	..	21,70,000	6·2
Purchased electric power	..	4,90,000	1·4
Packing materials	..	29,80 000	8·5
Works cost	..	2,98,80,000	85·4
Overhead charges.			
Interest (Factory)	..	37,80,000	10·8
Depreciation (Factory) ..	..	57,10,000	16·3
Housing estate overheads ..	..	3,90,000	1·1
Total cost f.o.r. factory	..	3,97,60,000	113·6

(b) APPROXIMATE COST OF PRODUCTION OF 350 000 TONS PER ANNUM OF SULPHATE OF AMMONIA AT SINDRI (DHANBAD).

		Rs. per annum.	Rs. per ton.
Raw materials			
Coal 249,000 at Rs. 12·5 per ton	..	31,10,000	8·9
Coke 178,000 at Rs. 32·6 per ton	..	58,20,000	16·6
Gypsum 536,000 at Rs. 23·6 per ton	..	1,26,40.000	36·1
Other materials	..	42,70,000	12·2
Labour and supervision	..	21,70 000	6·2
Purchased electric power	..	4,90,000	1·4
Packing materials	..	29,80,000	8·5
Works cost	..	3,14,80,000	89·9
Overhead charges.			
Interest (Factory)	..	39,40,000	11·3
Depreciation (Factory) ..	..	58,10,000	16·6
Housing estate overheads ..	..	3,90 000	1·1
Total cost f.o.r. factory	..	4,16,20,000	118·9

APPROXIMATE FACTORY AND DEPOT COSTS FOR VARIOU SCHEMES OF PRODUCTION OF 350,000 TONS PER ANNUM O SULPHATE OF AMMONIA.

	Output, tons per annum.	Annual Cost. Rs.	Cost per ton. Rs.
Scheme for six factories—			
Factory cost for—			
(*i*) Sindri (Dhanbad)	100,000	1,42,00,000	142·0
(*ii*) Amritsar	50,000	81,95,000	163·9
(*iii*) Moghal Sarai	50,000	87,65,000	175·3
(*iv*) Bombay	50,000	89,15,000	178·3
(*v*) Bezwada	50,000	91,75,000	183·5
(*vi*) Trichinopoly	50,000	91,90,000	183·8
Factory cost for scheme	350,000	5,84,40,000	167·(
Freight to depots	..	*Nil*	*Nil*
Depot cost	350,000	5,84,40,000	167·0
Scheme for three factories—			
Factory cost for—			
(*i*) Harduaganj	116,700	1,53,90,000	131·
(*ii*) Sindri (Dhanbad)	116,700	1,61,25,000	138·
(*iii*) Trichinopoly	116,700	1,71,85,000	147·
Factory cost for scheme	350,000	4,87,00,000	139·
Freight to depots	..	17,50,000	5·
Depot cost	350,000	5,04,50,000	144·
Scheme for two factories—			
Factory cost for—			
(*i*) Harduaganj	250,000	2,93,55,000	117·
(*ii*) Trichinopoly	100,000	1,51,20,000	151·
Factory cost for scheme	350,000	4,44,75,000	127·
Freight to depots	..	28,10,000	8·
Depot cost	350,000	4,72,85,000	135·
Scheme for single factory (a) Harduaganj—			
Factory cost	350,000	3,97,60,000	113·(
Freight to depots	..	43,10,000	12·:
Depot cost	350,000	4,40,70,000	125·!
Scheme for single factory (b) Sindri (Dhanbad)—			
Factory cost .. .. — ..	350,000	4,16,20,000	118·!
Freight to depots .. .. — ..	..	35,40,000	10·.
Depot cost	350,000	4,51,60,000	129·(

APPENDIX I.

The following information regarding the gypsum deposits of the Salt Range is reproduced from a report dated the 12th August 1944, by Mr. P. C. Das Hazra, B.Sc. (Lond.) of the Geological Survey of India............

INTRODUCTION.

I was deputed by the Director, Geological Survey of India, at the instance of the Fertiliser Technical Mission, to visit the Salt Range to collect data on the more accessible gypsum deposits. F. Ahmad, Assistant Geologist, and N. M. Khan, Post-Graduate Scholar, accompanied me for the period 11th July 1944 to 31st July, 1944.

The area examined comprises the foot-hills and scarp slopes of the Salt Range in Jhelum, Shahpur and Mianwali districts, Punjab. The following one inch to one mile topographical sheets of the Survey of India were used :—

43 H|2, 43 D|14, 38 P|15 and 38 P|9.

Assistance in obtaining labour etc. was kindly given by the officers of the Central Excise and Salt, Northern India, Salt Range Division.

GEOLOGICAL SEQUENCE.

The Geological sequence in the area is tabulated below :

Recent to sub-Recent beds	Miocene-Pliocene.
Siwaliks	
Murrees	
Unconformity.	
Bhadrar Beds	Laki.
Sakesar Limestone	
Nammal limestones and shales	
Patala shales	Ranikot.
Khairabad limestone	
Dhak Pass beds	
Unconformity.	
Lumshiwal sandstones	Cretaceous.
Belemnite shales	Lr. Cretaceous—Up. Jurassic.
Baroch limestones	Jurassic.
Variegated stage	
Kingriali dolomites	Upper Trias.
Kingriali sandstones	
Ceratite beds	Trias.
Upper Productus stage	Productus Limestone Series.
Middle Productus stage	
Lower Productus stage	
Lavender clay stage	Permian to Upp. Carboniferous.
Speckled Sandstone stage	
Conularia Beds	
Talchir Conglomerates	
Unconformity.	
Salt Pseudomorph beds	Cambrian.
Magnesian Sandstones	
Neobolus Shales	

Purple Sandstones	..	Lower Cambrian or pre Cambrian
~~		(discordant junction
overthrust.		
Saline series of the Salt Range. (*with gypsum*).		Probably Lower Eocene.

Detailed accounts of the stratigraphy of the Salt Range have been given by A. B. Wynne and others (A. B. Wynne—" On the geology of the Salt Range in the Punjab—*Mem. Geol. Surv. Ind.* XI, pt. 2 "). A recent publication is " The Economic Geology of the Northern Punjab with notes on adjoining portions of the North-West Frontier Province " by E. R. Gee *Trans. Min. Geol. Met. Inst. Ind.*, Vol., XXXIII, pt. 3, 1938. The principal deposits of gypsum are associated with the Saline Series.

Description of the Saline Series.

The Saline series is composed of massive gypsum, with bituminous shales and dolomite at the top, ferruginous salt-bearing marl in the middle, and gypseous marl with bituminous shales and dolomite at the base. Almost all the known important deposits of gypsum, some of which are now being worked belong to the Saline series. However, an appreciable quantity also occurs associated with the Lower Tertiary Limestones (Nummulitic)—apparently a product of chemical alteration of limestones. A typical example of the latter type of gypsum is found about 2-3 miles north-east-and east of Daud Khel in the hills on either side of the Kundian—Campbellpore section of the N. W. Railway.

Structure.

The foothills and lower scarp slopes of the Salt Range which contain the principal development of the Saline Series, have been affected by a series of tectonic movements (faults and shears) resulting in extensive disturbance of the rocks. The gypsum beds are, therefore, rarely continuous over long distances and are usually patchy and lenticular ; often they are badly contorted, e.g., gypsum of the Kalabagh Mari Indus area.

OCCURRENCES VISITED.

As mentioned above large deposits of gypsum are found principally in the Saline, series comprising the foothills and lower scarp slopes of the Range. The following localities were selected and examined in detail on account of the large reserves available and their accessibility.

1. **Khewra** ..	32°	38′	73°	1′	Sheet 43 H/2
2. **Dandot** ..	32°	39′	72°	58′	Sheet 43 D/14
3. **Sodi (sody)** ..	32°	38′	73°	2½′	Sheet 43 H/2
4. **Chanuwala** ..	32°	44′	73°	08′	Sheet 43 H/2
5. **Makrach** ..	32°	40′	72°	54′	Sheet 43 D/14
6. **Warcha Mandi** ..	32°	27′	71°	57′	Sheet 38 P/15
7. **Daud Khel** ..	32°	53′	71°	34′	Sheet 38 P/9
8. **Mari Indus** ..	32°	58′	71°	53′	Sheet 38 P/9

1. *Khewra.*

Khewra, the most important centre of the rock-salt industry in India is connected by a branch line of the N. W. Railway. Gypsum is chiefly found in the foothills and scarp slopes on either side of the Khewra gorge. The deposits are in seams and lenticles of varying thickness from 25 to 100 feet thick. The

quarries are mostly situated above the general level of the country, which has simplified the mining and transport of the material. The quarries are within a mile to two miles of the railhead. The transport from the quarries to the railway station is by means of pack animals. The quality of gypsum won is variable from very superior to ordinary quality.

2. *Dandot.*

The gypsum deposits are found in the foothills and scarp faces around the Dandot gorge. The main quarries are situated in a branch *nala*, Kalera wahan, about one mile west of the rail-head. The transport is by pack animals. Several grades of gypsum are available.

3. *Sodi.*

The deposits are on the same strike eastwards as the Khewra deposits. The quarried material is despatched from Sodi railway station about three miles from Khewra. The deposits are, on the whole, not of high-grade material.

4. *Channuwala.*

The gypsum deposits are found on the right-hand scarp slopes of Kas Kaura gorge, covering an area of about half a square mile. In the S. W. part it thickens to about 200 feet, but to the east, over long distance, the deposit is lenticular and in patches. Since a portion of the railway line has now been dismantled the nearest rail-head is about 3 miles away, where stone quarrying is still being carried on by the P. W. D.

5. *Makrach.*

Massive deposit of gypsum are found within the Makrach gorge and its tributaries for several miles upstream. They are thick in the N. W. portion of the gorge but contain many dolomite intercalations. Moreover the outcrops are discontinuous. The deposit is connected with the railway from Malakwal to Khusab by means of a six-mile trolley line used for the conveyance of coal from the Chittidand colliery from the exit of the gorge to Golpur railway station.

6. *Wareha Mandi.*

The gypsum deposits are connected with the branch railway line by means of an 8-mile siding from Gunjyal station on the Malkwal-Kundian section. In the scarp slopes gypsum is found in two thin parallel bands varying from 10 ft.—30 ft. in thickness. Gypsum is chiefly found on the eastern slopes of the Warcha gorge near its mouth. It is also found in the sides of the gorge further upstream.

7. *Daud Khel.*

The Kundian Campbellpore section, N. W. Railway practically cuts through the gypsum deposits east of Daud Khel. These deposits associated with the Tertiary limestones are quite distinct from the deposits of gypsum which belong to the Saline series. Here the beds are much less disturbed and are more regular in occurrence. In places they are from 50 to 100 feet in thickness.

The gypsum is very superior in quality and is almost free from impurities. It is chiefly quarried for the manufacture of special kinds of cement and Plaster of Paris.

8. *Mari Indus.*

The deposit is practically on the railway line. It contains frequent intercalations of barl, dolomite and shale and has been considerably contorted The Mari hill is well known on account of perfect crystals of quartz found in the gypsum, which are popularly known as the Mari diamonds.

Recently a proposal has peen submitted to the Government of India to commence an exploratory tunnel in the Mari hill for rock-salt. If the project is sanctioned and Mari hill is developed subsequently for rock-salt it is doubtful whether it would be possible to extract large quantities of gypsum.

ESTIMATION OF RESERVES.

Calculations of the reserve of the deposits examined have been based on the area occupied by the actual outcrops and on average thickness. The individual outcrops have been mapped on one inch maps, as far as possible. For rough calculation an area of one square mile has been taken as equivalent to 25 million square feet†. The volume thus obtained has been divided by a foot tonnage factor 20 in order to get the total reserve in tons. Thus the area of gypsum deposits at Khewra (divided intc 3 blocks for convenience in sampling) is about 3|8 square mile. Taking an average thickness of 50 feet of say 50 per cent. gypsum content—to allow for intercalations of dolomite, shale and marl etc.—the total reserves readily available amount to about 11. million tons.

The following table shows the approximate reserves of gypsum available in the areas examined :—

Location of deposit.	Area in sq. miles.	Average thickness in feet.	Percentage of gypsum contained.	Total quantity (in million tons).
1. Khewra (I, II, III)	3/8	50	50	11
2. Dandot	1/4	50	50	7
3. Sodi	1/3	30	20	2½
4. Chanwala..	1/2	40	40	10
5. Makrach	3/5	30	40	9
6. Waroha Mandi	1/4	10	40	1¼
*7. Daud Khel (N. & S.)	1/6 & 1/8+ X	100 (for N. & S. only.)	60	*25
Mari Indus	1	20	20	5
				70 million tons (+3/4)

†Actually it is 27 million square feet (approx.).

*The total of 25 *milion tons* ifor *three separate deposits* near Daudkhel is according to E.R. Gee.

X Area and thickness of (×) *have not been* estimated.

The total estimated reserves—70 million tons— may be regarded as a minimum quantity of gypsum available, without taking into consideration the probable extension of deposits beneath overburden [the calculations are based on outcrops only]. A large margin has been allowed for contained impurities (marls, dolomites, etc.) in the total bulk of the deposits, and in no case **has any deposit been regarded as containing more than 50 per cent. of clean " ore ", although in some cases it may be much more, say 60 to 80 per cent. It is highly probable that a considerable quantity of gypsum would be available by minor stripping of overburden, and the minimum reserve doubled.

**Except at Daudkhel, where gypsum content has been taken to be 60 per cent. of the total bulk

APPENDIX 2.

The following information regarding the gypsum deposits of Jodhpur and Bikaner States Rajputana is reproduced from a report dated the 12th August 1944, by Mr. P. K. Ghosh, D. Sc. (Lond.) D. I. C. Geologist, Mr. K. K. Dutta, A. I. S. M. and Mr. R. K. Taploo, M. Sc., Assistant Geologist, of the Geological Survey of India.

MAJOR DEPOSITS OF JODHPUR AND BIKANER.

Owing to the nearness of the railway, the gypsum deposits of (1) Kavas : (25° 52′ : 72° 35′), and of (2) Bhadwasi (27° 19′ : 73° 40′)—Pilanwasi (27° 20′ : 73° 43′, 3½ miles E.N.E. of Bhadwasi)—Dakoria (27° 20′ : 73° 44′, 3½ miles east of Bhadwasi) group of villages in Jodhpur State and of (3) Jamsar (28° 15′ : 73° 27′) in Bikaner State are of importance. The gypsum is being exported chiefly for the manufacture of cement, and to smaller extent as fertilizer in the agricultural farms in Bihar and the United Provinces. The estimated reserve of gypsum in these areas is a little over 13 million tons, the contents of the individual fields being as follows :—

State.	Deposits.	Unworked Area (in sq. miles)	Average thickness (in feet).	Total tonnage available at present.
Jodhpur ..	Kavas	0·37	2·7	1,050,000
,, ..	Bhadwasi	0·51	3	1,613,888
,, ..	Pilanwasi	0·25	4	1,040.207
,, ..	Dakoria	0·26	4·5	1,270,529
Bikaner ..	Jamsar	1·43	5·5	8,120,873*
	Total ..	..	..	13,095,497

The tonnage has been calculated on the basis of 27 cubic feet of gypsum to the ton or one|mile|foot = 1 million tons approximately.

Long before the beginning of the fairly recent commercial exploitation of the deposits, local use was found for the mineral. For over a century it has been used for plaster in buildings in towns and in rural areas, as bricks or roughly hewn blocks in the walls of huts in the neighbouring villages and also fertilizers. In this way nearly 35% of the Jamsar and Dakoria deposits, about 14% of the Bhadwasi and 12 per cent. of the Pillanwasi material have already been worked out, the tonnage shown above representing what is actually available now. The recorded tonnage supplied to Bikaner City for plastering during recent years is 12,500 tons per year. It is not known with certainty what quantities are used by the villages in their huts and in their farms ; possibly the consumption is about 4,000 tons per year. We have no data as to the quantity used in Jodhpur State for such purposes.

*Including 225,000 tons under the railway track and Station Buildings.

MINOR OCCURRENCES IN THE BIKANER STATE

Besides the above-mentioned areas, visits were also paid to the less known deposits in Bikaner State occurring at the following localities : (a) 3½ miles to the north-north-west of Jaimalsar (28°7′:73°5′) ; (b) 3¼ mile to the south of Kaoni (28°9′ ; 73°8′) being 3 miles to the east-south-east of (a) ; (c) Bharru (28°13′:73°15′). 11 miles to the east-north-east of (a). We were also able to locate two hitherto unknown deposits, *viz.*, (d) that at Harkasar (28°14′:73°11′), 7 miles to the west-south-west of Jamsar and (e) 2½ miles to the south-south-west of Dholera (28°17′:73°12′), which is about six miles from Jamsar. Being at some distance from the railways (6—13 miles), the deposits may not lend themselves to immediate exploitation. Although owing to the limited time at our disposal it has not been possible to judge with the same degree of accuracy their extent as in the case of the major deposits referred to above, a minimum estimate of the gypsum content of each has nevertheless been arrived at by surface indications and rare quarry faces when such exist, and occasional shallow pits when we were able to excavate them. Some samples have also been collected for analysis. We have no doubt that in this region other similar deposits exist which a thorough prospecting will bring to light.

The minimum estimate of the gypsum content of the areas in question is as follows :—

Jaimalsar	218,555	tons.
Kaoni	659,700	,,
Bharru	583,000	,,
Harkasar	500,000	,,
Dhobera	500,000	,,
Total ..	2,461,255	,,

The total minimum reserve known at present (inclusive of the major and minor deposits) is then 15,556,752 tons. Allowing even 25 per cent. on wastage in working the available amount is 11.7 million tons or say 11½ million tons. Leaving aside 1½ million tons for consumption in the cement industries during the next 20 years or so, the deposits will provide gypsum for 20 years to the fertilizer industry at the rate of 500,000 tons a year. With a somewhat improved method of working, the wastage may be considerably reduced and brought down to as low as 10 per cent. If the use of gypsum for the purpose of plastering on buildings and as bricks be discouraged, the corresponding amount may be conserved for the more important industries.

TRANSPORT

Except the Jamsar deposit (Bikaner State) across which the Railway track runs, and where the material is hand-carted to the railway, the gypsum is at present transported by camels from the quarries to the railhead over distances varying between ¼ to 3½ miles in the other areas. One camel is said to carry nearly 1½ tons a day on an average.

The Kavas deposit, occurring in four isolated lenticles, extends north-north-eastwards over a distance of nearly 2 miles from the neighbourhood of Kavas Railway Station on the Jodhpur-Hyderabad (Sind) metre gauge line, being 116 miles from Jodhpur. The Bhadwasi deposit, also occurring in several isolated patches, extends for nearly a mile and a half to the east and

about half a mile to the west of the Railway Station of the same name and Pillanwasi are 3½ miles to the east and to the E.N.E. respectively of Bhadwasi Station on the Jodhpur-Bikaner line, being 108 miles from Jodhpur and 63 miles from Bikaner. The Jamsar deposit is 19 miles to the N.N.E of Bikaner, the Jamsar Railway Station being situated almost at the central portion of the deposit. The present cost of transport and wastage in all these deposits may be lowered if the railway sidings are extended to the neighbourhood of the working sites.

The five minor deposits of Jaimalsar, Kaoni, Bharree, Harkasar and Dholera are within 6—16 miles of the existing railway lines. It will be economical in the long run to connect these deposits by railway, the approximate cost for haulage by locomotive will probably be between 2 and 3 annas per ton per mile. It is understood that Bikaner State has under contemplation the extension of the metre gauge line from Bikaner to Bahawalpur. The track which will evidently pass through the region in question, in addition to serving the normal traffic will help in opening up the deposits. As stated already, the region is likely to contain other deposits which a closer search may reveal.

MODE OF OCCURRENCE.

The gypsum deposits, often occurring in disconnected patches, are observed in the valleys among the sand dunes but it is not unlikely that they continue under the dunes. The estimates mentioned above take into account only such areas where the mineral has been observed either as a surface outcrop or in pits. The probable amounts existing under the dunes will no doubt increase the estimate, but the cost of working the additional amount will be higher owing to the thicker overburden.

Gypsum occurs as horizontal and bedded deposits, the average thickness of the fresh, workable portion varying between 1½ feet to 5½ feet in individual fields. Not infrequently the deposits are exposed at the surface although as a rule they are under a shallow mantle of top soil or wind-blown sand averaging a foot or so and seldom more than 3 ft. in thickness. In the central portions of the areas, the material is generally free from impurities, while towards the margins, though not invariably, it is less pure and appears to be mixed with a little sand. Occasionally thin bands of sandy intercalations are also met with, which are however easily eliminated from the product quarried for export. The deposits are underlain by salty sands. Sometimes a gypseous sand, averaging 9″ in thickness, intervenes between the base of the gyspum deposits and the underlying silty sand. When the soil cover is missing, the upper 6″ or so of the gypsum is decomposed and coated with a smear of a white and amorphous material which is mostly lime carbonate. Such portions are also eliminated from the quarried product.

The maximum thickness observed is 20 ft. as in the two quarries two furlongs to the west-south-west of Jamsar Railway Station. Such thickness is exceptional, though deposits 10 ft.—11 ft. thick are more commonly met with at Jamsar.

The deposits are bedded and sometimes contain shells of fresh or brackish water gasteropods indicating the deposition of gypsum in inland lakes. As a rule, the upper 5ft. or so of the deposits consist of a compacted mass of fine grained gypsum. Lower down the material is less compact and powdery often giving place to bands and aggregates of coarser selenite towards the base of the deposits.

APPENDIX 3

ESTIMATED COSTS OF WINNING GYPSUM AND ANHYDRITE.

1. Estimates of the capital expenditure and working costs involved in the winning of gypsum, using modern methods and equipment, were prepared by Mr. E. B. Lewis, Chief Mining Engineer, Salt Range, Central Excise, for the use of the Mission. Mr. Lewis' estimates refer to two locations in the Salt Range—Khewra and Daud Khel—and to Jamsar in Bikaner, quarrying of gypsum being assumed in the case of Daud Khel and Jamsar and mining of anhydrite in the case of Khewra. The figures of costs are summarised in the table below.

Estimated cost of winning Gypsum and Anhydrite.

Source.	Output. tons per annum.	Estimated capital. Rs. lakhs.	Interest & depreciation, Rs. per ton.	Working costs, Rs. per ton.	Total cost f. o. r. source, Rs. per ton.
Khewra	455,000	33·0	0·615	3·45	4·065
Daud Khel	550,000	14·5	0·30	2·075	2·375
Jamsar	146,000	12·0	0·95	1·36	2·31

2. In estimating the capital charges, interest has been taken at 4 per cent. and depreciation at 7½ per cent. on the capital costs. It should be noted that the output on which the estimate for Khewra is based assumes anhydrite to be the product; should these deposits prove to be largely gypsum, then a greater tonnage will be required and the cost per tón of gypsum will be slightly lower due to the greater ease of working this mineral. The estimated working costs include existing rates of royalty payments.

STATEMENT I.

List of Places visited by the Mission and the dates of visits.

Places visited.	Date of visit.
Patna	26th to 28 June, 44.
Dhanbad, Kumardhubi, Raniganj, Bumpore ..	29th & 30th June, 44.
Calcutta	1st to 6th July, 44.
Tatanagar	7th July, 44.
Cuttack	9th & 10th July, 44.
Madras	12th to 15th July, 44.
Aruvankadu	16th & 17th July, 44.
Mysore	18th & 19th July, 44.
Bangalore (visited Trichinopoly "Uttattur" by air)	20th to 23rd July, 44.
Hyderabad (Deccan)	25th to 27th July, 44.
Poona	28th & 29th July, 44.
Bombay (visited Kalyan by road)	30th July to 3rd Aug., 44.
Nagpur	5th Aug., 44.
Jubbulpore & Khamaria	6th to 8th Aug., 44.
Lucknow	9th Aug., 44.
Cawnpore	10th to 12th Aug., 44.
Aligarh & Harduaganj	13th Aug., 44.
Lahore	17th Aug., 44.
Khewra	18th & 19th Aug 44.
Mari Indus and Daud Khel	20th Aug., 44.
Amritsar	21st Aug., 44.
Bikaner (by air), & Jamsar	25th Aug., 44.
Pilanwasi, Badwasi & Dakoria .. .	26th Aug., 44.

STATEMENT II.

List of officials and others who were interviewed by the Mission.

Name.	Appointment or Firm.
NEW DELHI.	
Mr. A. W. H. Dean, C.I.E., M.C. ..	Chief Engineer, C. P. W. D.
Major General E. Wood, C.I.E. ..	Director General, Munitions Production.
Sir Hugh Raper	Transportation Member, Railway Board.
Sir William Stampe, C.I.E.	Irrigation Adviser to the Government of India.
Mr. L. N. Ahuja	M|s. Sepulchre Brothers.
Mr. Kashyap	Messrs. The Mining & Chemical Industries, Ltd.
Mr. H. N. Ganguli	Messrs. Natural Science (India), Ltd.
BIHAR.	
Mr. E. C. Ansorge, C.S.I., C.I.E., I.C.S.	Adviser to H. E. the Governor.
Mr. S. M. Dhar, C.I.E., I.C.S. ...	Development Commissioner.
Dr. H. K. Sen, M.A., D.I.C., D.Sc., F.N.I.	Director of Industries.
Mr. W. G. Came, C.I.E., I.S.E. ..	Chief Engineer & Secretary, P. W. D.
Mr. C. A. Maclean, C.B.E., M.C. ..	Deputy Director of Agriculture.
Mr. F. Sims, A.M.E.I.	Electrical Inspector & Engineer.
Mr. A. G. Bunn, I.C.S.	Additional Deputy Commissioner, Dhanbad.
Mr. O'Mulhachan	Executive Engineer, C. P. W. D.
Mr. F. W. Sharpley	Indian School of Mines.
Mr. Rackstraw	Messrs. Merz & McLellan, Consultants for Bihar Grid.
Mr. B. Wilson Haigh	Messrs. Bararee Coke Co., Ltd.
Dr. Sarkar	Messrs. Bararee Coke Co., Ltd.
Mr. Wormald	Messrs. Lodna Colliery, Co., Ltd.
Dewan Bahadur D. D. Thakkar ..	Colliery owner.
Mr. K. D. Worah	Colliery owner.
Mr. J. K. Dholakia	Colliery owner.
Rai Bahadur Bannerjee	Colliery owner.
Mr. A. C. Coombe	Messrs The Kumardhubi Engineering Works, Ltd.
Mr. Dixon	Messrs. The Kumardhubi Fireclay & Silica Works, Ltd.
Mr. H. V. Peeling	Messrs. Kulti Iron Works.
(Jamshedpur—Messrs. Tata Iron & Steel Co., Ltd.).	
Mr. J. J. Ghandy, C.I.E.	Agent & General Manager.
Mr. A. A. Bryant, O.B.E.	Deputy General Manager.
Mr. P. H. Kutar	General Superintendent.
Mr. B. R. Kagal	Town Administrator.
Mr. N. H. Haley	Assistant General Superintendent.
Mr. E. J. Parkinson	Chief Metallurgist.
Mr. W. H. Ames	Chief Engineer.
Mr. E. T. Warren	Chief Superintendent Blast Furnaces & Coke Ovens.
Mr. Ghosh	Chief Electrical Engineer.
Mr. Mazumdar	Officer-in-Charge of Reservoir Scheme.
Mr. Saranghdar	Officer, Filtration & distribution water.

BENGAL.

The Hon'ble Khawaja Sir Nazimuddin, K.C.I.E.	Chief Minister.
The Hon'ble Khwaja Mr. Shahabuddin, C.B.E.	Minister for Commerce, Labour & Industries.
The Hon'ble Khan Bahadur Saiyed Muazzamuddin Hosain.	Minister for Agriculture.
Mr. M. K. Kirpalani, I.C.S.	Secretary, Commerce, Labour & Industries Deptt.
Mr. S. Dutt, I.C.S.	Secretary, Agriculture Department.
Mr. A. Schofield	British Trade Commissioner.
Mr. K. Elmhurst	Agriculture Adviser.
Mr. M. Carberry, D.S.O., M.C., I.A.S. ..	Director of Agriculture.
Dr. R. L. Datta, D.Sc.	Industrial Chemist.
Dr. Sankaran	Professor of Biochemistry.
Mr. P. C. Young, C.B.E.	Coal Commissioner to the Government of India.
Mr. J. F. Parr	Steel Commssioner to the Government of India.
Sir Robert Marriott	Controller of Railways.
Mr. J. Harrison	Chief Mining Engineer.
Major T. F. Borwick, C.I.E., D.S.O. ..	Additional Director General, Ordnance Factories.
Brig. M. H. Cox, O.B.E.	Deputy Director General, Ordnance Factories.
Lt.-Col. W. R. Leake	Assistant Chief Engineer, Ordnance Factories.
Mr. Stephen Kaye	Director of Steel Control (Pipes & Tubes Section).
Mr. K. L. H. Wadley	Executive Engineer, C. P. W. D.
Dr. A. Jardine	Messrs. Jessop & Co., Ltd.
Mr. H. W. T. Hain	Messrs. Braithwaite & Co., Ltd.
Mr. K. Chatterton	Messrs. Burn & Co., Ltd.
Mr. W. J. Savage	Messrs. Oriental Gas Co., Ltd.
Mr. N. J. Bates	Messrs. Hooghly Docking & Engineering Co., Ltd.
Mr. G. W. A. Wylie	Messrs. Garden Reach Workshops, Ltd.
Mr. E. L. Goodman	Messrs. Britannia Engineering Co., Ltd.

ORISSA.

Mr. H. Lal, I.C.S.	Director of Development.
Mr. J. Shaw	Superintending Engineer, Floods & Drainage, P. W. D.
Mr. M. Patnaik	Provincial Biochemist.
Mr. P. Parija	Principal, Ravenshaw College.
Dr. B. Prasad	Professor of Biochemistry, Ravenshaw College.
Dr. G. B. Bannerji	Professor of Physics, Ravenshaw College.

MADRAS.

Mr. S. V. Ramamurthy, C.I.E., I.C.S. ..	Adviser to H. E. the Governor.
Mr. S. Y. Krishnaswamy, I.C.S. ..	Special Development Officer.
Mr. T. Sivasanker, I.C.S.	Secretary, Development Department.
Mr. R. M. Sundaram, I.C.S.	Additional Secretary, Development Department.

MADRAS—*contd.*

Mr. K. Ramunni Menon, I.C.S. ..	Secretary, P. W. D.
Rao Bahadur N. Govindaraja Ayengar ..	Chief Enigneer, Irrigation..
Lt.-Col. M. G. Platts, O.B.E., M.C., I.S.E.	Chief Engineer, Electricity.
Rao Bahadur Dr. B. V. Nath, I.A.S.	Director of Agriculture.
Mr. A. Khaleeli, I.C.S.	Director of Industries & Commerce.
Mr. W. G. Dyson, I.F.S.	Chief Conservator of Forests.
Mr. A. N. Chopra, I.S.E.	Superintending Engineer, C. P. W. D.
Dr. M. S. Krishnan	Geological Survey of India.
Mr. Mitchell	Collector of Trichinopoly.
The Rajah of Venkatagiri	.. ..
Sir J. Higgins, K.C.B., K.C.M.G. .	Messrs. Travancore Chemicals & Fertilizers, Ltd.
Mr. McCarty	Messrs. Travancore Chemicals & Fertilizers, Ltd.
Mr. E. D. Pawley	Messrs. Travancore Chemicals & Fertilizers, Ltd.
Mr. V. Seshasayee	Seshasayee Bros., Ltd.
Mr. A. G. Krishnaswami	Seshasayee Bros., Ltd.
Mr. Raman	Seshasayee Bros., Ltd.
Mr. G. S. Sankaran	Trichinopoly Mining Works, Ltd.
Mr. C. Elphinston	Messrs. Parry & Co., Ltd.
Mr. S. G. H. Davis ..	Messrs. Parry & Co., Ltd.

ARUVANKADU.

Mr. H. E. Page, I.O.S.	Superintendent, Cordite Factory.

MYSORE.

Mr. N. Madhava Rau	Dewan & President in Council.
Mr. M. A. Srinivasan	Minister for Industry.
Mr. E. V. Ganapati Iyer	Controller of Civil Supplies.
Mr. Rao	Director of Chemicals.
Sir C. V. Raman	Indian Institute of Science.
Mr. B. Visvanath	Mysore Iron & Steel Works.
Mr. H. K. Ramiengar	Mysore Chemicals of Fertilizers, Ltd.
Mr. Dalziel	Mandya Distillery.
Mr. J. Hamilton	Hindustan Aircraft, Ltd.
Mr. H. E. Hoteko	Hindustan Aircraft, Ltd.

HYDERABAD.

Mr. Ghulam Mohammad, C.I.E. ..	The Hon'ble the Finance Minister.
Mr. W. V. Grigson, I.C.S.	The Hon'ble the Revenue Minister.
Nawab Mahdi Yar Jung Bahadur ..	Secretary, Commerce & Industries.
Nawab Mahmud Yar Jang Bahadur ..	Secretary, Post War Planning.
Col. E. W. Slaughter, C.B.E. ..	Agent & General Manager, H.E.H. the Nizam's Railway.
Nawab Rais Yar Jung Bahadur ..	Secretary, Commerce & Industries.
Nawab Zain Yar Jung Bahadur ..	Osmania University.
Nawab Mahmud Yar Jung Bahadur ..	Osmania University.
Dr. M. Qureshi	Osmania University.
Mr. Liaq Ali	Osmania University.
Dr. Krishna	Soil Scientist.
Rai Sahib Kalidas Sawhney	Director of Agriculture.
Dr. A. C. Heron	Adviser, Department of Geology & Mines.
Mr. H. C. H. Armstead	Director, City Electricity Department.

KIRKEE.

Mr. R. Huddart, I.O.S.	Superintendent, High Explosives Factory.

BOMBAY.

Mr. G. F. S. Collins, C.S.I., C.I.E. I.C.S.	Adviser to H. E. the Governor.
Mr. I. H. Taunton, C.I.E., I.C.S. ..	Adviser to H. E. the Governor.
Mr. P. B. Advani	Special Officer Electric Grid.
Mr. M. J. Desai, I.C.S.	Secretary, Revenue Department.
Mr. R. H. Hammett, C.E.	Secretary, P. W. D.
Mr. J. W. McEllhinney, I.C.S. ..	Secretary, Education Department.
Mr. W. J. Jenkins, C.I.E., I.C.S. ..	Director of Agriculture.
Rai Bahadur S. S. Salimath	Deputy Director of Agriculture.
Dr. N. R. Damle, M.Sc.	Industrial Chemist.
Dr. K. Vankataraman	Head of University, Chemical Technological Department.
Dr. John Matthai	Managing Director, Tata Iron & Steel Co., Ltd.
Mr. Walchand Hirachand	Chairman, Premier Construction Co., Ltd.
Mr. K. J. Somaiya	Godavari Sugar Mills, Ltd.
Mr. H. K. Kirpalani, C.I.E., I.C.S. ..	Late Dewan, Bikaner State.
Mr. W. S. Nelson	Tata Hydro-Electric Co.
Mr. E. Dibben	Traction Superintendent, G.I.P. Rly.
Mr. M. Turner	Hindustan Vanaspati Manufacturing Co.
Dr. R. R. Hattiangadi	Associated Cement Cos., Ltd.
Mr. W. E. Gladtone	Bombay Gas Co., Ltd.
Mr. E. W. A. Richardson	Richardson & Cruddas.
Mr. Meswani	Acme Manufacturing Co., Ltd.
Mr. Z. T. Kaziji	Messrs. Garlick & Co.

CENTRAL PROVINCES.

Mr. T. C. S. Jayaratnam, C.I.E., I.C.S. ..	Financial Adviser to H. E. the Governor.
Mr. A. L. Binney, C.I.E., I.C.S. ..	Development Adviser to H. E. the Governor.
Mr. A. G. F. Farquhar, O.B.E., I.C.S. ..	Revenue Secretary.
Mr. B. A Smellie, O.B.E.	Agricultural Secretary.
Mr. R. H. Hill, I.A.S.	Director of Agriculture.
Mr. K. D. Guha	Director of Industries.
Mr. K. P. Minocha	Electrical Adviser.
Sardar Bahadur Ishar Singh ..	Labour Commissioner.
Mr. P. S. Sharangpani, I.S.E. ..	Superintending Engineer, P.W.D.
Mr. N. K. Patterson, O.B.E., I.C.S. ..	Collector & District Commissioner, Jubbulpore.
Maharaja Nagendra Singh, I.C.S. ..	Deputy Commissioner, Itarsi.
Mr. Dwarka Nath Khurana	Executive Engineer, P.W.D.
Mr. H. J. Garrad, I.O.S.	Chief Superintendent, Ordnance Factory, Khamaria.
Mr. J. B. S. Hatton	Superintendent, Gun Carriage Factory, Jubbulpore.

UNITED PROVINCES.

Sir A. William Ibbotson, C.I.E., M.B.E., M.C., I.C.S.	Adviser to H. E. the Governor.
Mr. E. de V. Moss, C.I.E., I.C.S. ..	War Production Commissioner.
Mr. H. S. Stephenson, I.C.S. ..	Secretary to H. E. the Governor.
Mr. A. P. Watal, I.S.E.	Superintending Engineer, Project.

UNITED PROVINCES—*contd.*

Mr. C. W. Casse, M.I.C.E.	Chief Mech. Engr. Industries Deptt.
Mr. S. T. Munsey, I.S.E.	Chief Engineer, Western Canals.
Mr. F. H. Hutchinson, I.S.E.	Chief Engineer, Eastern Canals.
Rai Bahadur R. L. Sethi, M.R.A.S., I.A.S.	Cane Commissioner.
Rao Sahib Pandit P. S. Viswanathan ..	Agricultural Engineer.
Mr. L. C. Jain, I.C.S.	Director of Industries.
Mr. T. Swaminathan, I.C.S. ..	Deputy Secretary.
Major T. R. Low, M.C., I.A.S. ..	Additional Director of Agriculture (War Production).
Mr. C. Maya Dass, I.A.S.	Director of Agriculture.
Mr. K. I. Brown, M.B.E.	Electrical Engineer, Hydro-Electricity Construction Division, Aligarh.
Mr. Auden	Geological Survey of India.
Mr. G. Misra, O.B.E.	Upper India Chamber of Commerce.
Mr. Caws	Agricultural Expert, Begg Sutherland & Co.
Mr. Debicharan Gupta	Cawnpore Steel Works.
Mr. Ram Narain Garg	Industrialist.

PUNJAB.

Mr. P. K. Kaul, I.C.S.	Secretary, Electricity & Industries Department.
Mr. B. A. Kureshi, I.C.S.	Under Secretary, Electricity & Industries Department.
Mr. V. F. Critchley, A.I.E.E. ..	Chief Mechanical Engineer, P. W. D.
Mr. Fairfield	Mining Engineer.
Mr. M. H. Mahmood, Bar-at-Law ..	Director of Industries.
Dr. J. L. Sarin, PhD.	Industrial Chemist.
Malik Sultan Ali Noon, I.A.S. ..	Director of Agriculture.
Mr. E. B. Lewis, M.B.E.	Chief Mining Engineer.
Mr. E. McGlashan	General Manager, Alkali Works, Alkali Chemical Corporation of India.
Mr. A. S. Irvine	Works Manager, Alkali Works, Alkali Chemical Corporation of India.
Mr. A. King	Chief Engineer.

BIKANER.

His Highness the Maharaja of Bikaner	
Mr. K. M. Panikar	Dewan.
Rao Bahadur Thakkar Pratap Singh ..	Home & Development Minister.
Dr. C. D. Pande	Mining Engineer.
Mr. R. H. T. Mackenzie ..	Chief Engineer, P. W. D.
Mr. H. N. Ganguli	Director, Natural Science (India), Limited.
Mr. Pareek	Director, Natural Science (India), Limited.

DOCHI (PATIALA STATE).

His Highness the Maharaja of Patiala	
Mr. H. S. Malik, C.I.E., I.C.S. ..	Prime Minister.

STATEMENT III.

List of Engineering and other firms whose works were visited by the Mission.

	Name of firm.	Works visited
1.	Acme Manufacturing Co., Ltd.	Bombay.
2.	Alkali & Chemical Corporation of India Ltd.	Calcutta & Khewra.
3.	Bararee Coke Co., Ltd	Kusunda.
4.	Braithwaite & Co., Ltd.	Kidderpore.
5.	Britannia Engineering Co., Ltd.	Titagarh.
6.	Burn & Co., Ltd.	Howrah.
7.	Garden Reach Workshops, Ltd.	Calcutta.
8.	Garlick & Co., Ltd.	Bombay.
9.	Hindustan Aircraft Works Ltd.	Bangalore.
10.	Hooghli Docking & Engineering Co., Ltd.	Calcutta.
11.	Indian Hume Pipe Co., Ltd.	Bombay.
12.	Indian Iron & Steel Co., Ltd.	Kulti & Hirapur.
13.	Investa Machine Tool Works.	Bombay.
14.	Jessops & Co., Ltd.	Dum Dum.
15.	Kumardhubi Engineering Works Ltd.	Kumardhubi.
16.	Kumardhubi Fireclay & Silica Works Ltd.	Kumardhubi.
17.	Lodna Colliery Co., Ltd.	Lodna.
18.	Mysore Chemicals & Fertilizers Ltd.	Belagula.
19.	Orissa Engineering Workshops	Cuttack.
20.	Richardson & Cruddas	Bombay.
21.	Tata Iron & Steel Co., Ltd.	Jamshedpur.
22.	U. P. Engineering Workshops	Cawnpore.

STATEMENT IV.

List of firms whose representatives were interviewed by the Mission.

	Name of firm.	Place.
1.	Associated Cement Co., Ltd.	Bombay.
2.	Begg Sutherland & Co.	Cawnpore.
3.	Bombay Gas Co., Ltd.	Bombay.
4.	Hindustan Vanaspati Manufacturing Co., Ltd. ..	Bombay.
5.	Imperial Chemical Industries (India) Ltd. ..	Calcutta.
6.	Makerwal Colliery	Mari Indus.
7.	Mandya Distillery	Mysore.
8.	Mining & Chemical Industries Ltd.	Delhi.
9.	Natural Science (India) Ltd.	Calcutta.
10.	Oriental Gas Co., Ltd.	Calcutta.
11.	Parry & Co.	Madras.
12.	Sepulchre Brothers	Delhi.
13.	Seshasayee Brothers Ltd.	Trichinopoly.
14.	Travancore Chemicals & Fertilizers Ltd. ..	Madras.

L68D—650—8-7-45—GIP
Reg. No. 327 HE (C) '49-250.